Survey of Shallow Benthic Habitat: Eastern Shore and Cape Breton, Nova Scotia

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by

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CONTENTS

	Page
Abstract/Résumé	v
Introduction	1
Materials and Methods	1
Diving Survey	3
Temperature	6
Results	6
Physical habitat	6
Temperatures	9
Transect profiles	12
Sea urchin distribution	13
Quantitative sea urchin sampling	15
Seaweed occurrence by depth and exposure	15
Seaweed distribution from Cape Sable Island to Bay St. Lawrence	19
Discussion	24
Physical habitat	24
Seaweeds	24
Sea urchins	25
References	26
Appendix 1: Profiles of each transect surveyed	29
Appendix 2: Development of lobster larvae in oceanic Nova Scotia	49

LIST OF TABLES

Page

Table 1. Physical characteristics of the shoreline by exposure class. 7

Table 2. Physical characteristics of the shoreline by county. 7

Table 3. Rocky substrate types by county and exposure, expressed as fractions of the total stations for each county or exposure. 9

Table 4. Degree days (above 0°C) per week at thermograph sites in 1984. 10

Table 5. Summary of transect data. 12

Table 6. Number of stations with each urchin density, classified by exposure and depth range. 14

Table 7. Means of sea urchin test diameter, density, and biomass from quadrat samples. 15

Table 8. Percentage of the stations with a given sea urchin density and exposure where each seaweed type occurred. . . . 18

Table 9. Geographical distribution of seaweeds. 20

LIST OF FIGURES

Fig. 1. The Altantic coastline of Nova Scotia. 2

Fig. 2. Spooling disposable transect line onto a squid reel. 4

Fig. 3. Transect lengths and depths at each exposure. Bars represent mean ± 1 s.e. of mean. 8

Fig. 4. Temperatures obtained from recording thermographs in 1984. . . 11

Fig. 5. Sea urchin size frequencies from quadrat samples. 16

Fig. 6. Frequency of occurrence of seaweed taxa by depth and exposure. Each dot represents presence of the alga at one station. . . . 21

ABSTRACT

Moore, D.S., R.J. Miller, and L.D. Meade. 1986. Survey of shallow benthic habitat: Eastern shore and Cape Breton, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 1546: v + 49 p.

During 1984-85, 2,000 km of the Nova Scotia coast from Ship Harbour to Bay St. Lawrence were surveyed to determine the area of habitat sea urchins and seaweeds share, sea urchin size frequencies and biomass, the extent of sea urchin mass mortalities, the extent of colonization by seaweeds, the physical characteristics of the habitat, and summer-autumn temperature regimes. A previous survey in 1982 provided similar data for 2,900 km of Nova Scotia coast from Cape Sable Island to Ship Harbour. Recent mass mortalities of sea urchins were a major ecological event worth documenting as a case history, and as a baseline for comparing future changes in sea urchins, seaweeds, and associated commercially important species.

The length of shoreline bordered by rocky sublittoral was determined by cruising the shore in an outboard runabout. Divers recorded depth, distance from shore, substrate type, percentage bottom cover by seaweeds, dominant seaweed taxa present, and sea urchin density at 1,044 stations on 59 transects. Urchin size frequency and biomass were measured on 11 transects, and recording thermographs were moored at five sites.

About one-half of the shoreline was bordered by rocky sublittoral, and 81% of this was on the open-exposed coast. Total area of rocky habitat to 15 m depth was 373 km^2. Most of the rocky sublittoral from western Chedabuco Bay to Scatarie Island was still urchin dominated, but 240 km of shore between Ship Harbour and Chedabucto Bay had been released from urchin grazing. The biomass of sea urchin mass mortality occurring from 1980-85, as estimated from both surveys, totaled 270,000 t live weight. Where urchins were present their biomass ranged from 394-1011 g/m^2 on the eastern shore and 376-605 g/m^2 in Cape Breton.

Chondrus crispus and Fucus spp. occurred more frequently in this survey than in the previous one, particularly on the Cape Breton coast north of Scatarie Island. Laminaria longicruris, Laminaria digitata, Alaria esculenta, Sacchoriza dermatodea, and Agarum cribrosum all occurred less frequently north of Scatarie Island.

Cumulative degree days were 25% higher north of Scatarie Island than west of Scatarie Island on the eastern shore. Summer temperatures exceeded 18°C at all sites and were warm enough for lobster larvae to develop from hatching to settling.

RÉSUMÉ

Moore, D.S., R.J. Miller, and L.D. Meade. 1986. Survey of shallow benthic habitat: Eastern shore and Cape Breton, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2546: v + 49 p.

En 1984-1985, on a procédé à des relevés sur 2 000 km le long de la côte de la Nouvelle-Écosse, de Ship Harbour à Baie St. Lawrence pour déterminer la superficie d'habitat que se partagent les oursins et les algues marines, les fréquences des tailles et la biomasse des oursins, l'ampleur de la mortalité de masse chez l'oursin, l'ampleur de la colonisation par les algues marines, les caractéristiques physiques de l'habitat et les régimes de température été-automne. Une enquête antérieure réalisée en 1982 a fourni des données semblables pour 2 900 km le long de la côte de la Nouvelle-Écosse, de Cape Sable Island à Ship Harbour. La mortalité de masse récente qui a frappé l'oursin constitue un événement écologique majeur qui mérite d'être documenté à titre de cas particulier et à titre de données de base pour des comparaisons futures en ce qui concerne les changements chez les oursins, les algues marines et les espèces importantes commercialement qui leur sont associées.

La longueur de littoral bordé par une zone sublittorale rocailleuse a été déterminée par des sorties en hors-bord le long du littoral. Des plongeurs ont noté la profondeur, la distance par rapport à la terre, le type de substrat, le pourcentage du fond marin couvert par des algues, les taxons dominants d'algues marines et la densité de la population d'oursins dans 1044 stations réparties sur 59 transects. La fréquence des tailles et la biomasse des oursins ont été mesurées dans 11 transects, et des thermographes ont été mouillés à cinq endroits.

Environ la moitié du littoral était bordé par une zone sublittorale rocailleuse, dont 80% était situé sur la côte ouverte. La surface totale de l'habitat rocailleux jusqu'à une profondeur de 15 m était de 373 km^2. La plus grande partie de la zone sublittorale rocailleuse de l'ouest de la baie Chedabucto à l'île Scatarie était encore dominée par les oursins, mais une longueur de 240 km de rivage, entre Ship harbour et la baie Chedabucto, ne subissait plus le pâturage par les oursins. La biomasse d'oursins disparus par suite des épisodes de mortalité en masse survenus de 1980 à 1985 a été estimée, à partir des deux enquêtes, à 270 000 t (poids vif). Là où les oursins étaient présents, leur biomasse variait de 394 à 1 011 g/m^2 sur la côte est et de 376 à 605 g/m^2 au Cap Breton.

Chondrus crispus et Fucus spp. étaient plus fréquents au cours de la présente enquête qu'au cours de l'enquête précédente, surtout sur la côte du Cap Breton au nord de l'île Scatarie. Laminaria longicuruis, Laminaria digitata, Alaria esculenta, Sacchoriza dermatodea et Agarum cribrosum étaient moins fréquents au nord de l'île Scatarie.

Le nombre de degrés-jours cumulatifs était plus élevé de 25% au nord de l'île Scatarie qu'à l'ouest de l'île Scatarie, sur la côte est.

Les températures estivales dépassaient 18°C dans tous les endroits et étaient suffisamment élevées pour permettre le développement des larves de homard depuis l'éclosion jusqu'au moment où elles se déposent sur le fond marin.

INTRODUCTION

An underwater survey was conducted during 1982 and 1983 to determine the extent of sea urchin, Strongylocentrotus droebachiensis, mass mortalities, subsequent expansion of seaweed distribution, and the area of habitat these organisms share (Moore and Miller 1983; Miller 1985a). The survey extended from the southern most tip of mainland Nova Scotia to Ship Harbour on the eastern shore (Fig. 1). Of the 2,800 km of shore surveyed, 1,400 km was bordered by a rocky sublittoral.

This report presents data collected on a similar survey, during July through October 1984 and July and August 1985, from Ship Harbour to the northern tip of Nova Scotia on Cape Breton Island. A total of 2,000 km of shoreline were examined. The survey was designed to:

1) measure shoreline bordered by rocky and "soft" (sand, gravel, and mud) sublittoral habitat;
2) measure the area of rocky sublittoral habitat to a depth of 15 m;
3) categorize rocky habitat by its exposure to waves;
4) describe the distribution and abundance of macrophytes and sea urchins;
5) determine the extent of sea urchin deaths during recent mass mortalities; and
6) describe the summer-autumn temperature regime for shallow inshore waters in the area.

Visual approximations of algal cover and urchin densities were chosen rather than the collection of quantitative samples in order to accommodate more stations and habitat description.

These results will serve as a baseline for comparing future sea urchin and seaweed abundances, and yields of associated commercially important species. They may also be useful for estimating coastline vulnerability to oil spills, rafting ice, or siltation. Mann (1977; 1982) considered seaweed important to lobster yields, whereas Miller (1985b) concluded that the data support was equivocal. These baseline data may help in eventually resolving this problem.

MATERIALS AND METHODS

MEASUREMENT OF SHORELINE

The coast was surveyed from an outboard runabout and, where necessary, the bottom was viewed through a glass-bottom bucket to locate shallow, rocky bottom (bedrock, boulders, and cobble) and soft bottom (gravel, sand, and mud). Rocky shoreline was defined as having a minimum of 50% rock substrate for 40 m or more offshore. Because of the width restriction, channels or coves less than 80 m wide were excluded.

Lengths of rocky and soft shoreline were measured, at chart datum, with a digitizer (HP9874A) from the following Canadian Hydrographic Service charts.

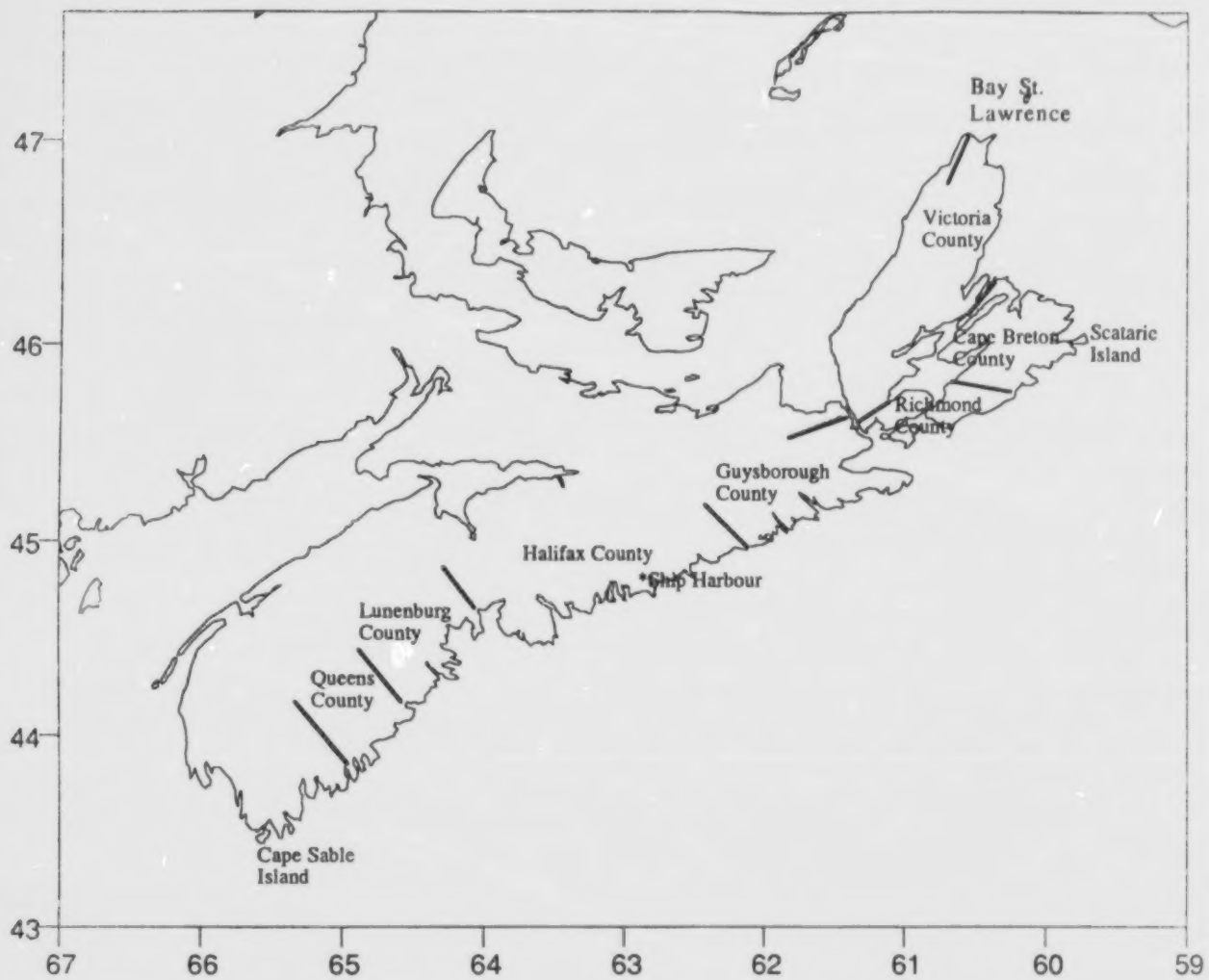

Figure 1. The Atlantic coastline of Nova Scotia.

Chart Name	Number	Scale
Red Point to Guyon Island	4374	1:75,000
Guyon Island to Flint Island	4375	1:75,700
Flint Island to Cape Smokey	4367	1:75,200
Cape Smokey to St. Paul Island	4363	1:74,500
Ship Harbour	4352	1:24,500
Popes Head to Charles Island	4353	1:18,200
Sheet Harbour, Mushaboom Harbour and Spry Bay	4361	1:24,300
Beaver Harbour	4364	1:24,200
Necum Teuch Harbour and Vicinity	4355	1:24,200
Liscomb and Marie Joseph Harbours	4356	1:24,300
Port Bickerton to Liscomb Island	4285	1:25,000
Country Island to Port Bickerton	4284	1:25,000
Berry Head to Country Island	4283	1:25,000
White Head to Berry Head	4282	1:25,000
Approaches to Canso Harbour	4280	1:37,500
Canso Harbour to the Strait of Canso	4307	1:37,500
St. Peters Bay to the Strait of Canso	4308	1:37,500
St. Peters Bay	4275	1:20,000
Main-a-dieu Passage	4377	1:18,000
Sydney Harbour	4315	1:20,879
Great Bras D'Or and St. Andrews Channel	4277	1:40,000

DIVING SURVEY

Transects were positioned every 16 km of rocky shoreline using smaller scale charts (1:74,500 to 1:108,800). To avoid bias in locating transects, mainland shore within a 5-min square of latitude and longitude was measured first, then each island within the square was measured beginning and ending at its southern tip.

Transects ran perpendicular to the shoreline to a depth of 15 m below chart datum, or to where the bottom became soft, whichever came first. Infrequently the ending depth exceeded 15 m where the bottom dropped off sharply; or conversely, the transect was long and a fishing vessel's sounder was used to approximate the transect end. Although seaweed, especially Agarum, does occur deeper, 0-15 m was considered to encompass over 90% of the algal biomass (Mann 1972; Edelstein et al. 1969; Sharp et al. 1981) and primary production.

Disposable transect lines were prepared in the laboratory by marking cotton butchers' twine at 10 m intervals with waterproof ink and spooling the line on squid jig reels (Fig. 2). Using an electric drill, two persons could prepare 1,300 m of transect line in 30 min.

Local fishing vessels (8 to 13 m) were hired to transport divers to the transect sites. After locating the starting point the boat was anchored offshore where the transect was expected to end. Two divers were transported to shore in a skiff. One diver located the starting point, defined as the bottom of the Ascophyllum zone, typically about 0.5 m above chart datum. The free end of the transect line was tied to a rock or a firmly anchored piece of vegetation, and a compass course set perpendicular to shore and toward the fishing vessel.

Figure 2. Spooling disposable transect line onto a squid jig reel.

This diver layed out the transect line and the second recorded observations at each 10 m mark (station).

For long transects, between 200 m and 500 m (length estimated before entering the water), observations were made at the first five stations, up to six stations were skipped, and another series of five observations was made. This procedure was continued to the end of the transect.

On transects over 500 m, divers entered the water at about 250 m intervals and made observations at five successive stations. The total length of these transects was estimated using radar on the fishing vessel.

The following data were recorded on waterproof paper by divers at each station on the transect:

1) distance from the start of the transect;
2) depth, in feet, taken from a diver's depth gauge which was periodically calibrated against a marked line from the surface. Using time of day and tide tables, depth was corrected to meters below chart datum;
3) substrate type as one or more of the following categories (eg. 3/6= scattered boulders on sand),
   1) bedrock,
   2) dense boulders (boulders covered entire bottom),
   3) scattered boulders,
   4) cobble (<20 cm),
   5) gravel (<4 cm),
   6) sand, and
   7) mud;
4) percent plant cover estimated by the proportion of rocky bottom which was obscured by macroalgae when viewed from above. An area of approximately 1 m radius around each station was viewed for percent plant cover and algal taxa;
5) occurrence of algal types in decreasing order of abundance. Types recorded were filamentous (a catchall of species including summer ephemerals), Fucus spp., Chondrus crispus, Laminaria longicruris, Laminaria digitata, Sacchoriza dermatodea, Alaria esculenta, and Agarum cribrosum;
6) sea urchin density was estimated visually as being within ranges of <1, 1 to 10, 10 to 100, or >100 per square meter. Divers calibrated their visual estimates by counting the numbers of sea urchins in several 0.25 m^2 quadrats at the beginning of the survey. Only sea urchins larger than 10 mm test diameter were included in the estimates.

Sea urchin density was also determined by quadrat sampling on 11 transects. All urchins of 10 mm diameter or larger were collected from eight to eighteen 0.25 m^2 quadrats, at sites 1-4 m and 8-11 m deep. Urchin diameters were measured with calipers and tallied in 10 mm groups.

Two criteria were used for selecting transects for urchin sampling. Urchin density had to be moderate or high, and at least one transect was required for every 100 km of rocky coastline.

EXPOSURE

Exposure to waves is a major factor influencing sea urchin and macrophyte distribution and abundance (Dalby et al. 1978; Jones and Demetropoulos 1968; Hiscock 1983; Moore and Miller 1983). The open Atlantic coast of Nova Scotia is exposed to near maximum wave force when compared with other coastlines throughout the world. The wave climate of the open Atlantic Ocean determines these forces (Hans Neu, Bedford Institute of Oceanography, Dartmouth, N.S., pers. comm.). Therefore, the following exposure scale was based first on exposure to the open ocean and second on exposure to locally generated waves:

1) in a bay without line of site to the open ocean and with a <20° angle open to ≥8 km fetch within the bay;
2) in a bay with a 1° to 20° angle open to the ocean or with no line of sight to the ocean and a 20° to 45° angle open to ≥8 km fetch within the bay;
3) in a bay with a 21° to 40° angle open to the ocean or with a 1° to 20° angle open to the ocean and >45° angle open to ≥8 km fetch within the bay;
4) on open coastline with a 41° to 90° angle open to the ocean; and
5) on open coastline with ≥90° angle open to the ocean.

The angle and distance measurements were taken at the point a transect met the shore.

TEMPERATURES

Disease-induced mortalities of sea urchins and development time of lobster larvae are temperature dependent (Miller and Colodey 1983; Scheibling and Stevenson 1984; Templeman 1936). To better understand these events in the field, five sites, shown on the map foldouts, were selected to monitor seawater temperatures. Ryan Model J thermographs with accuracy of ± 0.5°C and recording time of 6 mo were used. Exposed sites were selected to avoid locally high water temperatures which occur in sheltered bays during summer.

RESULTS

PHYSICAL HABITAT

The length of shoreline for an exposure class (l_e) was calculated as the number of transects at that exposure divided by the total number of transects (t_e/T) times the total length of rocky shoreline (L). The area of rocky

$$l_e = \frac{t_e L}{T}$$

habitat for an exposure class was l_e times the average length of transects at that exposure. These calculations assume that the transect locations were an unbiased sample of the true proportions of shoreline at each exposure. We have no reason to doubt this assumption.

Length of rocky shoreline was 1,036 km, and area of rocky habitat was 373 km. Sixty percent of the length and 81% of the area were on open coast, (Table 1). Both length and maximum depth of transects tended to increase with exposure (Fig. 3). The 985 km of soft shoreline was found mostly in Exposures 1 and 2. Locations of rocky and soft shorelines are shown on the foldouts in the back of this report.

Table 1. Physical characteristics of the shoreline, by exposure class.

Exposure	No. of transects	Max. depth		Length (m)		Rocky habitat	
		Mean	$S_{\bar{x}}$[a]	Mean	$S_{\bar{x}}$[a]	Length (km)	Area (km^2)
1	1	4.9	-	40	-	18	0.7
2	6	7.4	1.9	162	59	105	17.1
3	13	9.5	1.2	236	62	228	53.9
4	21	12.0	0.8	432	83	369	159.3
5	18	13.0	0.9	450	85	316	142.2
Total:	59					1,036	373.2

[a] $S_{\bar{x}} = s/\sqrt{N}$ = standard deviation of the mean.

Eastern Halifax County (Ship Harbour to the Guysborough County line - foldouts) included 18% of the total shoreline surveyed, but only 7% of the rocky habitat area. Low exposure and associated narrow width of rocky habitat explain this difference (Table 2).

Table 2. Physical characteristics of the shoreline, by county.

Area	Shoreline lengths (km)		No. of transects	Mean length (m)	Mean exposure	Rocky habitat area (km^2)
	Rocky	Soft				
Eastern Halifax Co.	209	145	11	130	2.9	27
Guysborough Co.	321	443	19	413	4.0	133
Richmond Co.	179	242	10	433	4.0	78
Cape Breton Co.	193	94	11	388	3.9	75
Victoria Co.	134	61	8	399	4.3	53

Guysborough County included 38% of the total shoreline and 36% of the rocky habitat. Although a relatively high percentage of the shoreline was soft, the rocky shoreline was exposed and transects were long (Table 2). Most of the soft shoreline was in Country Harbour and Whitehead Harbour.

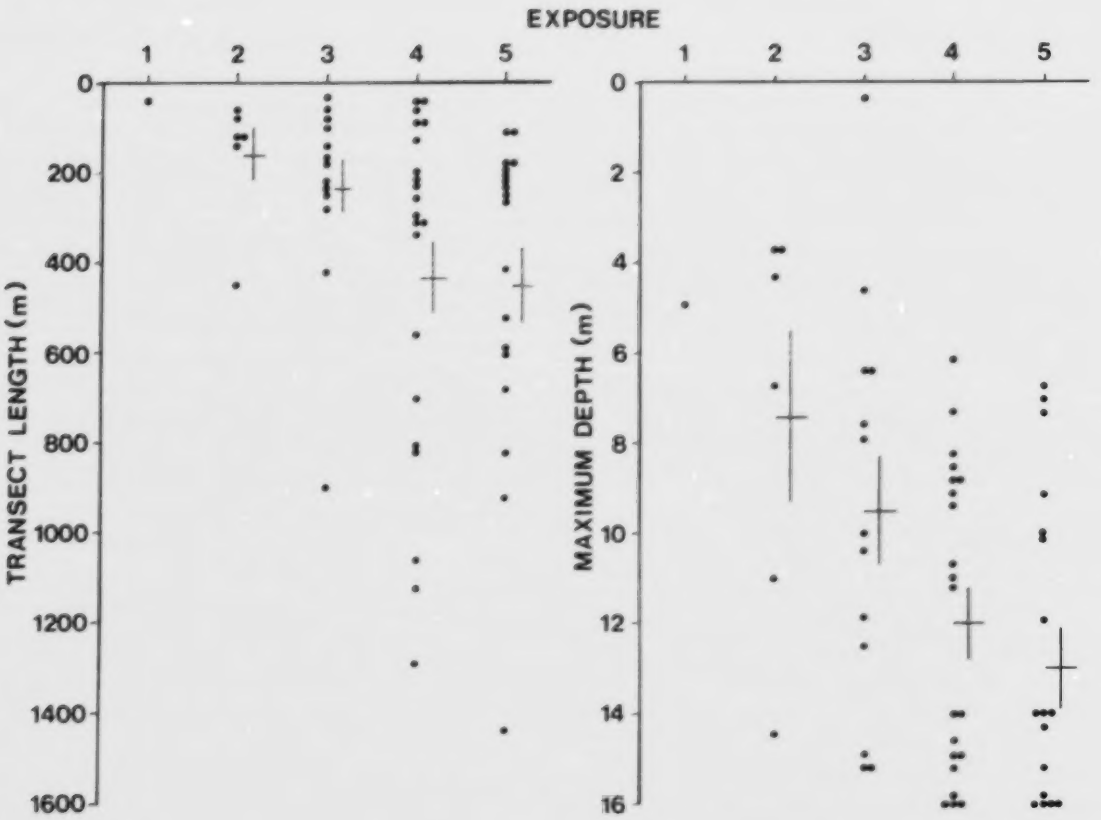

Figure 3 Transect length and depth versus exposure. Bars represent the mean ± 1 s.e.

Richmond County included 17% and 21% of the total shoreline and rocky habitat respectively, and had similar shoreline characteristics to Guysborough County (Table 2). Most of the soft shoreline was north and west of Isle Madame.

Cape Breton and Victoria Counties included 20% and 14% respectively of the rocky habitat area. Both counties have relatively straight, exposed shore with the length of rocky shoreline more than double the soft shoreline (Table 2). Sydney Harbour and St. Ann's Harbour contained most of the soft shoreline.

Bedrock and boulders are more prevalent in exposed areas, varying from 78% of the stations at Exposure 5 to none at Exposure 1 (Table 3). The information on rocky substrate type by county is also included in Table 3.

Table 3. Rocky substrate types by county and exposure, expressed as fractions of the total stations for each county or exposure.

Area	Bedrock	Boulders[a]	Mixed sizes and smaller rocks[b]
Exposure			
1	0.0	0.0	1.0
2	0.08	0.28	0.64
3	0.09	0.34	0.57
4	0.23	0.32	0.45
5	0.27	0.51	0.22
East Halifax Co.	0.12	0.59	0.29
Guysborough Co.	0.24	0.34	0.42
Richmond Co.	0.17	0.26	0.57
Cape Breton Co.	0.26	0.43	0.31
Victoria Co.	0.10	0.44	0.46

[a]Substrate Types 2, 3, 1/2, 1/3, 1/2/3, and 3/2.
[b]Substrate Type 4 and all combinations including Types 4, 5, 6, or 7.

TEMPERATURES

Temperature data from the five thermograph sites are presented in Figure 4, and degree days (above 0°C) per week are given in Table 4. Murray Point, about 30 km south of Ingonish, supplements data missing from Ingonish after the thermograph was washed ashore in late August; and the Magdalen Island site is an example of summer temperatures at a shallow site in the Gulf of St. Lawrence. Murray Point and Magdalen Island temperatures were taken from Dobson and Petrie (1985).

All four sites from Little Harbour to Gabarus showed similar temperature regimes from Days 161-293 (June 9 through October 19) for which the total degree days are nearly equal (Table 4). In contrast, Ingonish temperatures

Table 4. Degree days (above 0°C) per week at thermograph sites in 1984.

Calendar days	Little Harbour 3 m depth	Port Bickerton 3 m depth	Canso 4 m depth	Gabarus 3 m depth	Ingonish 3 m depth	Murray Pt. 9 m depth	Magdalen Islands 4.5 m depth
140-146	46.0(4)[a]						61.0
147-153	31.3		29.3(6)[a]				73.7
154-160	37.7	37.2	34.1	31.9(4)			68.4
161-167	48.5	45.2	45.6	48.2	42.9(3)[a]		81.1
168-174	44.3	46.2	51.5	37.7	51.2		86.0
175-181	55.6	56.1	46.3	54.6	62.3		93.6
182-188	64.6	58.1	63.3	55.7	71.7		96.7
189-195	54.1	58.5	36.2	47.1	93.3		119.0
196-202	54.9	58.2	56.2	71.9	106.2		124.7
203-209	46.0	47.9	58.4	72.3	119.6	96.3	135.5
210-216	60.0	73.8	75.9	95.7	121.1	103.1	137.6
217-223	87.1	94.3	89.4	104.8	131.8	113.4	151.0
224-230	122.3	123.6	102.7	111.4	134.9	118.7	153.2
231-237	117.4	115.8	113.5	113.4	133.0	120.1	141.7
238-244	111.7	111.1	122.7	106.4	120.9(4)[a]	117.4	130.3
245-251	108.2	111.9	115.6	99.7		111.2	126.5
252-258	99.3	97.2	114.7	92.1		108.6	115.0
259-265	93.7	96.9	96.3	91.3		101.1	102.0
266-272	91.0	87.1	95.9	79.9		92.7	88.5
273-279	88.4	85.0	87.1	70.6		84.9	80.7
280-286	58.3	53.0	73.0	47.5		72.8	57.5
287-293	69.0	63.6	70.1	53.5(5)[a]		68.6	60.1
294-300		61.2	72.6				67.9(4)[a]
301-307		56.8	66.7				
308-314		53.4	59.0				
315-321			54.5				
322-328			49.3(4)[a]				
161-293	1,474.4	1,483.5	1,514.4	1,453.6	1,828.8[b]		2,080.7

[a]At the beginning and end of some records, weekly values were extrapolated and the actual days of data are noted in brackets.

[b]Ingonish temperatures were used from Days 161 to 240 and Murray Point temperatures from Days 241-293.

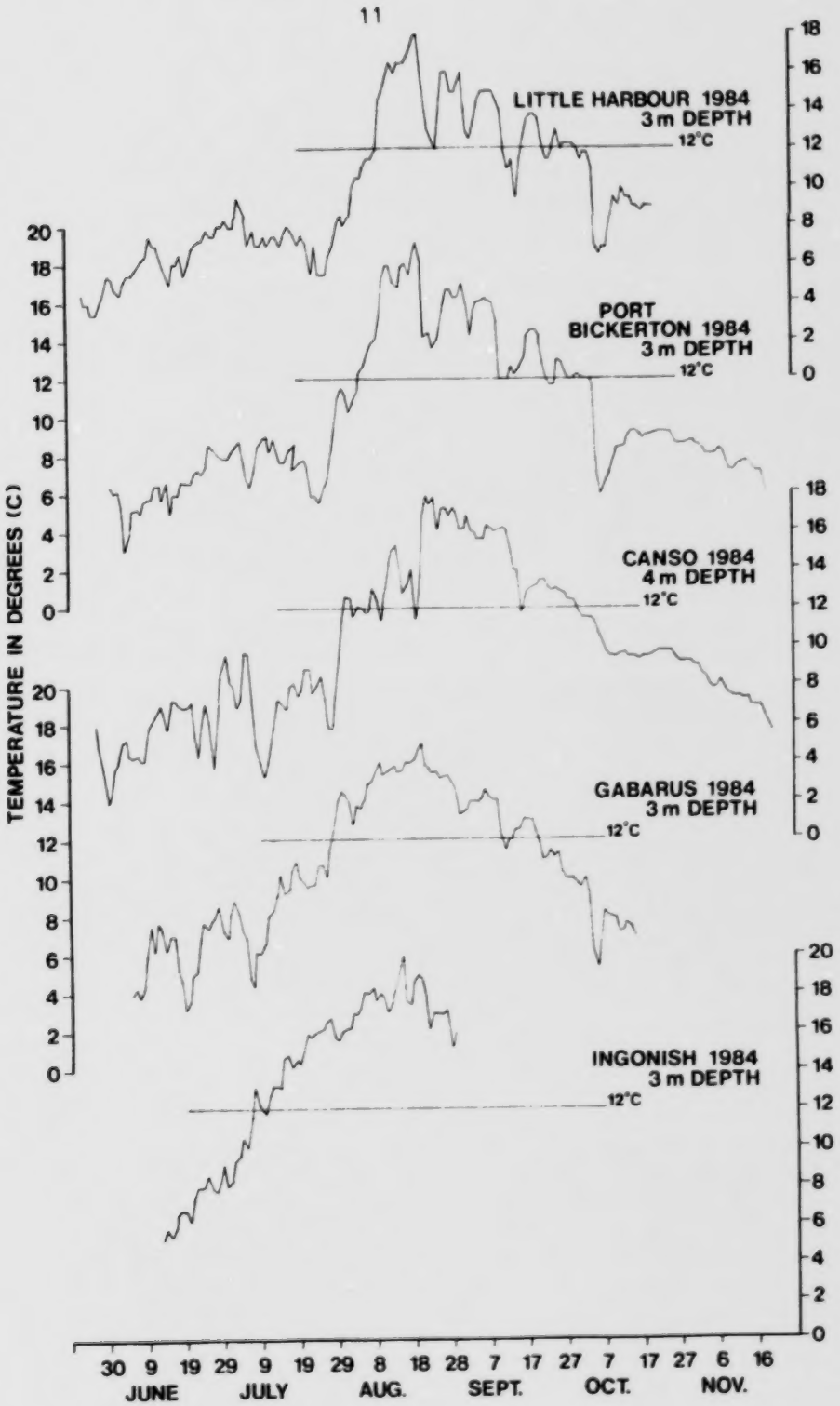

Figure 4. Temperatures obtained from recording thermographs in 1984.

rose earlier and, if Murray Point data are substituted after late August, fell later, giving 25% more accumulated degree days for the period than the other sites on the Atlantic coast. The total degree days for the summer at Ingonish were closer to the total for the Magdalen Islands than to Atlantic coast sites.

TRANSECT PROFILES

Depth, distance from shore, substrate type, macrophyte taxa, and urchin density on the 59 transects are shown in Appendix 1. Transect data are also summarized in Table 5.

Table 5. Summary of transect data.

Transect number	Length (m)	Maximum depth (m)	Exposure index	Urchin per m^2		Mean % algal cover	
				Survey	Fall 1985	Survey	Fall 1985
1	220	6.4	3	<1	-	70	-
2	40	4.9	1	<1	-	50	-
3	60	10.0	3	<1	-	70	-
4	60	4.3	2	<1	-	10	-
5	130	14.6	4	<1	-	70	-
6	240	14.0	5	<1	-	80	-
7	140	11.0	2	<1	-	60	-
8	200	14.0	5	<1	-	80	-
9	120	3.7	2	1-10	-	20	-
10	80	6.7	2	<1	-	40	-
11	260	5.5[a]	5	1-10	1-10	60	80
12	140	7.9	3	<1	-	50	-
13	700	11.0	4	10-100	1-10	50	90
14	310	14.0	4	10-100	<1	20	80
15	600	7.3	5	10-100	1-10	90	100
16	250	7.6	3	<1	-	80	-
17	300	8.5	4	10-100	10-100	50	40
18	590	16.8	5	1-10	1-10	90	70
19	450	3.7	2	1-10	10-100	20	0
20	200	14.9	4	10-100	10-100	80	40
21	820	10.7	4	10-100	-	60	-
22	40	8.8	4	10-100	10-100	50	40
23	60	15.2	4	100+	-	40	-
24	340	16.4	4	<1	10-100	90	60
25	260	16.2	4	10-100	10-100	50	20
26	140	8.2	4	1-10	1-10	60	100
27	1,060	14.9	4	10-100	10-100	0	0
28	90	15.8	4	10-100	10-100	20	10
29	90	9.1	4	10-100	-	10	-
30	1,290	14.0	4	10-100	-	10	-
31	100	11.9	3	1-10	-	50	-
32	1,120	17.4	4	10-100	-	0	-
33	120	14.9	2	<1	-	60	-
34	810	11.2	4	10-100	-	20	-

...Cont'd

Table 5. Cont'd

Transect number	Length (m)	Maximum depth (m)	Exposure index	Urchin per m²		Mean % algal cover	
				Survey	Fall 1985	Survey	Fall 1985
35	230	7.3	4	10-100	-	30	-
36	900	14.9	3	<1	-	60	-
37	400	9.1	5	1-10	-	50	-
38	220	6.7	5	1-10	-	70	-
39	180	10.1	5	10-100	-	10	-
40	250	15.2	5	10-100	-	20	-
41	420	15.2	3	10-100	-	10	-
42	180	15.2	3	10-100	-	10	-
43	220	9.4	4	10-100	-	10	-
44	190	16.8	5	10-100	-	60	-
45	110	7.0	5	10-100	-	70	-
46	170	10.4	3	10-100	-	10	-
47	280	6.4	3	<1	-	40	-
48	30	0.3	3	<1	-	10	-
49	1,440	19.5	5	1-10	-	30	-
50	920	11.9	5	10-100	-	40	-
51	310	6.1	4	<1	-	90	-
52	240	4.6	3	<1	-	70	-
53	80	12.5	3	1-10	-	60	-
54	680	14.3	5	1-10	-	70	-
55	180	14.0	5	10-100	-	60	-
56	820	17.7	5	10-100	-	40	-
57	110	10.0	5	10-100	-	40	-
58	560	8.8	4	10-100	-	30	-
59	520	15.8	5	1-10	-	50	-

[a]Transect stopped at this depth because the divers were one-half the distance between two shores. This depth was not used in the depth versus exposure analysis.

SEA URCHIN DISTRIBUTION

During the transect survey the Halifax-Guysborough County line was the approximate eastern boundary of recent mass mortalities. Piles of empty sea urchin tests were seen on most transects in Halifax County, and Transect 9 was the only one of ten transects where urchin densities averaged >1/m² (Table 5). Transects east of Halifax County generally had higher urchin densities. Among the eight exceptions, Transects 16, 51, and 52 were in areas where low salinities or sedimentation could have excluded urchins. Reasons for scarcity at the other sites (Transects 24, 33, 36, 47 and 48) are unknown, but local outbreaks of disease prior to the survey are a possibility.

When estimates of urchin density at each station were grouped by depth range and exposure (Table 6), it showed that they were found at most exposures and depths. However, they were most prevelant at Exposures 3, 4, and 5 and between 5 and 10 m. At Exposure 2, abundance was highest from 0-5 m. This distribution probably reflects a prefered level of wave turbulence.

Most Guysborough County transects were reoccupied during the autumn of 1985. Since the previous year, urchin densities were reduced to 10/m² or less on Transects 13, 14, and 15 (Table 5). Assuming a predisease density of 480g/m² (Miller and Colodey 1983), 240 km of rocky shoreline from Transects 1 to 15, and an average habitat width of 220 m (mean length of Transects 1-15), 25,000 t of urchins would have died between Ship Harbour and Country Harbour.

Table 6. Number of stations, with each urchin density classified by exposure and depth range.

Exposure	Urchins per m²	Depth							
		0-5 m		5.1-10 m		10.1-16 m		Total	
		n	%	n	%	n	%	n	%
2	<1	2	6	4	80	6	100	12	28
	1-10	23	72	1	20	0	-	24	53
	10-100	7	22	0	-	0	-	7	16
	100+	0	-	0	-	0	-	0	-
Total:		32		5		6		43	
3	<1	42	60	14	33	11	41	67	48
	1-10	2	3	8	19	3	11	13	9
	10-100	20	29	20	48	13	48	53	38
	100+	6	9	0	-	0	-	6	4
Total:		70		42		27		139	
4	<1	25	16	22	20	21	22	68	19
	1-10	38	24	18	17	10	11	66	18
	10-100	94	59	66	61	62	65	222	61
	100+	2	1	2	2	2	2	6	2
Total:		159		108		95		362	
5	<1	54	43	8	9	8	8	70	23
	1-10	39	31	20	23	43	44	102	33
	10-100	32	26	60	68	44	45	136	44
	100+	0	-	0	-	2	2	2	1
Total:		125		88		97		310	

QUANTITATIVE SEA URCHIN SAMPLING

The quadrat samples give urchin density and biomass for specific sites and are suitable for comparisons with future samples from these sites.

The size frequencies (Fig. 5) consistently include a wide range of sizes, suggesting a range of age classes at each site. However, there was a tendency toward the smaller sizes on the eastern shore and larger sizes in Cape Breton (Table 7).

Table 7. Mean sea urchin test diameter, density, and biomass from quadrat samples.

Area	Depth (m)	Test diameter (mm)	Density (no./m²)	Biomass (g/m²)
Eastern Shore	<5	32	59	1,101
(Transect 1 to 30)	>5	22	45	394
Total:		29	54	836
Cape Breton	<5	35	14	376
(Transects 31 to 59)	>5	32	27	605
Total:		34	20	478

SEAWEED OCCURRENCE BY DEPTH AND EXPOSURE

Presence of seaweed types at each of the 1,044 stations was summarized by depth, Exposures 1-5, and high or low sea urchin density (Fig. 6). The percentage of stations with a given exposure and urchin density where a seaweed type occurred was also summarized (Table 8). For example, L. longicruris occurred at 19% of the 48 stations with >10 urchins/m² and with Exposure 3. In the previous survey (Moore and Miller 1983) sea urchin density was classed as <1/m² and >1/m² for examination of seaweed occurrence. However, the present survey included more stations with densities of 1-10/m² and fewer with <1/m², hence the change in the low-density class.

Difference in algal occurrence for the two urchin densities was tested with a 2 by 2 contingency table; for example,

No. of stations	No. of stations with urchin density >10/m²	<10/m²
with L. longicruris	108	354
without L. longicruris	304	278

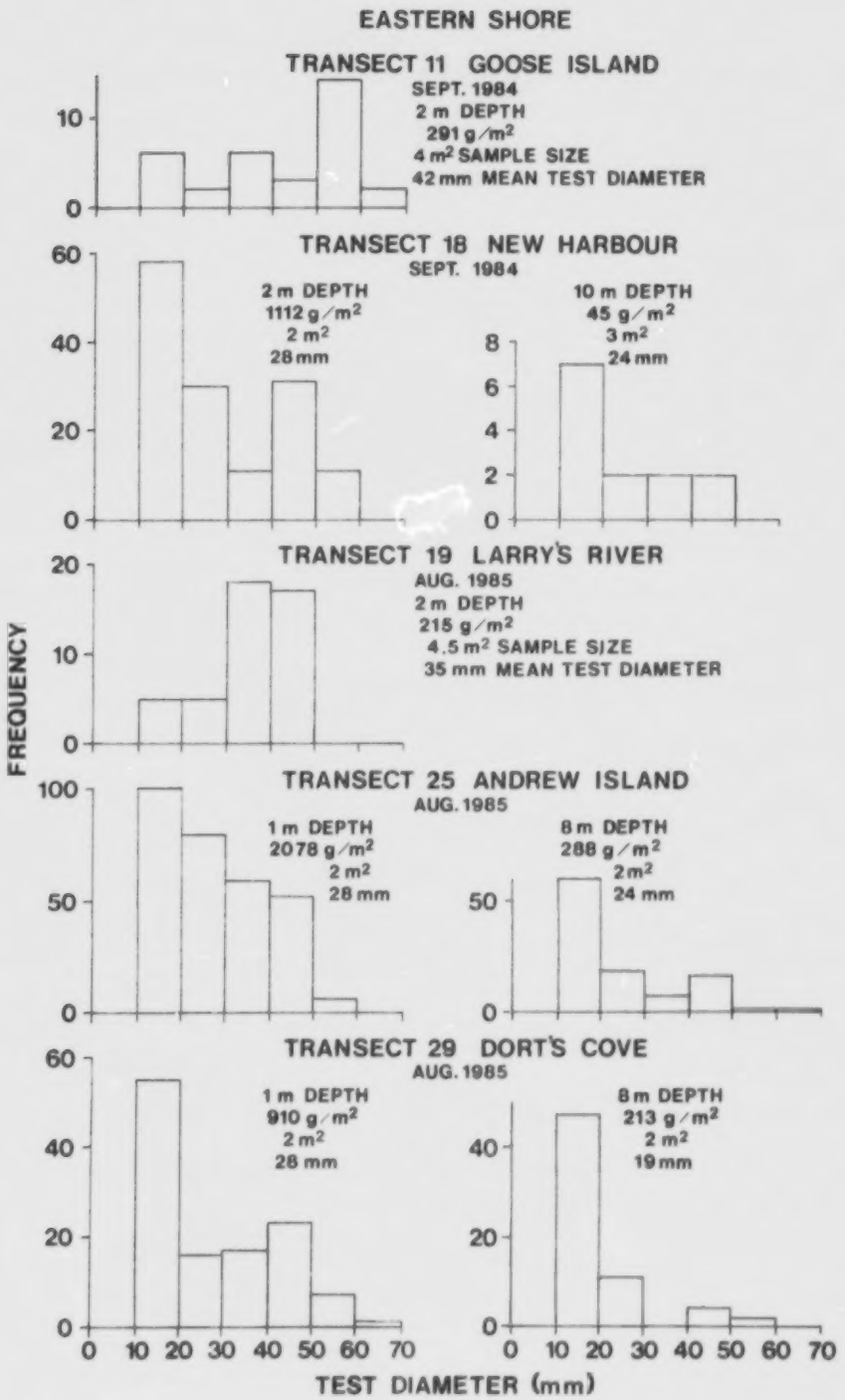

Figure 5. Sea urchin size frequencies from quadrat samples.

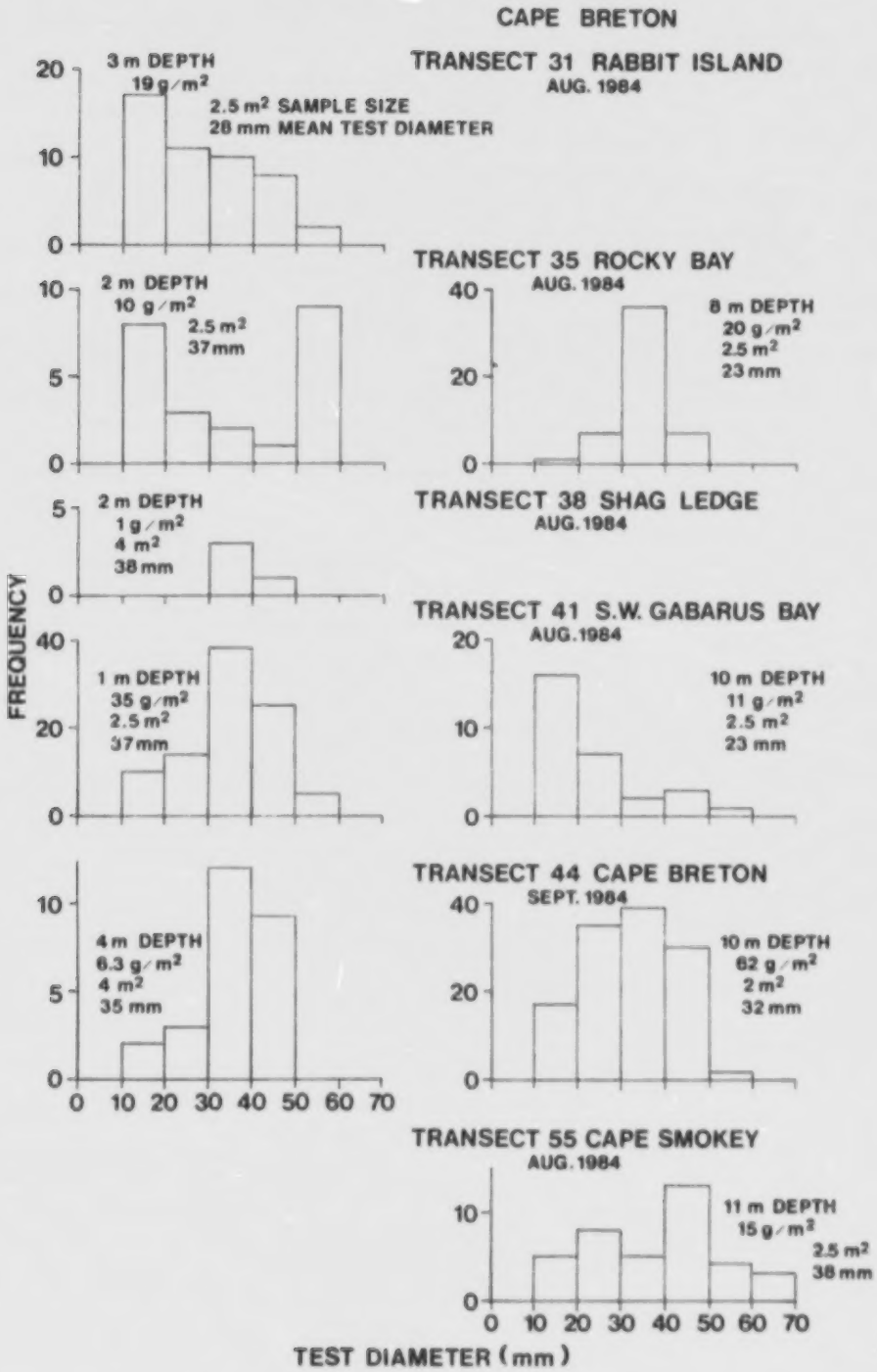

Figure 5. (cont'd)

Table 8. Percentage of the stations at a given sea urchin density and exposure where each seaweed type occurred.

Treatment 1 (>10 sea urchins/m^2):

	Exposure					
	1	2	3	4	5	All exposures
L. longicruris	-	0	19	14	50	26
L. digitata	-	0	0	9	13	9
Alaria sp.	-	0	0	10	7	8
Saccorhiza sp.	-	0	6	8	21	12
Agarum sp.	-	0	2	12	10	10
Fucus spp.	-	0	4	4	7	5
Chondrus crispus	-	0	10	1	7	4
Filamentous	-	29	44	39	75	56
No. of stations	0	7	48	221	136	412

Treatment 2 (<10 sea urchins/m^2):

	Exposure					
	1	2	3	4	5	All exposures
L. longicruris	0	33	51	55	68	56
L. digitata	0	0	7	24	29	19
Alaria sp.	0	0	0	21	3	7
Saccorhiza sp.	0	0	2	17	10	9
Agarum sp.	0	0	4	15	9	9
Fucus spp.	0	41	41	23	27	31
Chondrus crispus	40	24	45	27	20	29
Filamentous	80	79	66	73	75	72
No. of stations	5	66	164	188	209	632

Five of eight seaweeds occurred most frequently with low sea urchin density (chi-square >10, P<0.01). L. longicruris was the most common kelp at both high and low urchin density, occurring at 56% of stations with low urchin density and 36% with high urchin density. L. digitata, a kelp common on exposed shores (Mann 1972), was present at 9% and 19% of stations with high and low urchin density respectively. It was found at Exposure 3 only with low urchin density. Fucus spp. was more common (31% versus 5%), occurred deeper, and occurred in more sheltered locations with low urchin density. Occurrence of C. crispus (29% vs 4%), a fleshy red algae, were similar to that of Fucus spp. Filamentous algae occurred at 51% and 72% of stations with high and low urchin density respectively. All the above algal taxa were found on the shallow portions of exposed transects even where sea urchins were abundant. This high-energy environment is a refuge from urchin grazing (Himmelman and Steele 1971; Miller 1985a).

The remaining three species of kelp occurred with frequencies from 7-12%, and were about equally common (P>0.05) with high and low urchin densities. Agarum cribrosum was found in deep exposed habitats and is not a preferred food of sea urchins (Vadas 1977). Alaria esculenta is confined to exposed locations (Himmelman and Steele 1971) which can offer a refuge from grazing. It was found deeper where urchin densities were low. Saccorhiza dermatodea is a quick-colonizing annual (Breen and Mann 1976). Its equal frequency with high and low urchin density was unexpected.

SEAWEED DISTRIBUTION FROM CAPE SABLE ISLAND TO BAY ST. LAWRENCE

The coast was divided into three regions:

1) Cape Sable Island to Ship Harbour (data from Moore and Miller 1983);
2) Ship Harbour to Scatarie Island; and
3) Scatarie Island to Bay St. Lawrence.

Region 3 was defined by its distinct oceanography (El-Sabh 1980; Sutcliffe et al. 1976) and temperature regime (see "Discussion" section). Ship Harbour was chosen as the boundary between Regions 1 and 2 because it was the approximate eastern limit of the complete urchin die-off in 1983 (Miller 1985a) and it lies approximately mid-way between Cape Sable Island and Scatarie Island.

Within each region the percentage of the stations with each seaweed type is given in Table 9. Only stations at appropriate exposures for a seaweed type were used, and only stations with <1 urchin/m^2 in Region 1 and <10 urchins/m^2 in Regions 2 and 3 were included to minimize the effects of grazing.

Table 9. Geographical distribution of seaweeds.

Seaweed	Exposure	Region[a]	Number of stations	% of stations with seaweed
L. longicruris	3-5	1	534	62
	3-5	2	359	70
	3-5	3	172	42
L. digitata	4-5	1	317	42
	4-5	2	240	38
	4-5	3	129	9
A. esculenta	4-5	1	317	36
	4-5	2	240	17
	4-5	3	129	0
S. dermatodea	3-5	1	534	42
	3-5	2	359	11
	3-5	3	172	10
A. cribrosum	3-5	1	534	14
	3-5	2	359	11
	3-5	3	172	6
Filamentous	1-5	1	655	85
	1-5	2	455	59
	1-5	3	172	84
Fucus spp.	2-5	1	655	N/A[b]
	2-5	2	455	28
	2-5	3	172	47
C. crispus	1-5	1	655	13
	2-5	2	427	22
	2-5	3	172	39

[a]Region codes: 1-Cape Sable to Ship Harbour
2-Ship Harbour to Scatarie Island
3-Scatarie Island to Bay St. Lawrence

[b]*Fucus* was rarely encountered in this region, and its occurrence was not recorded.

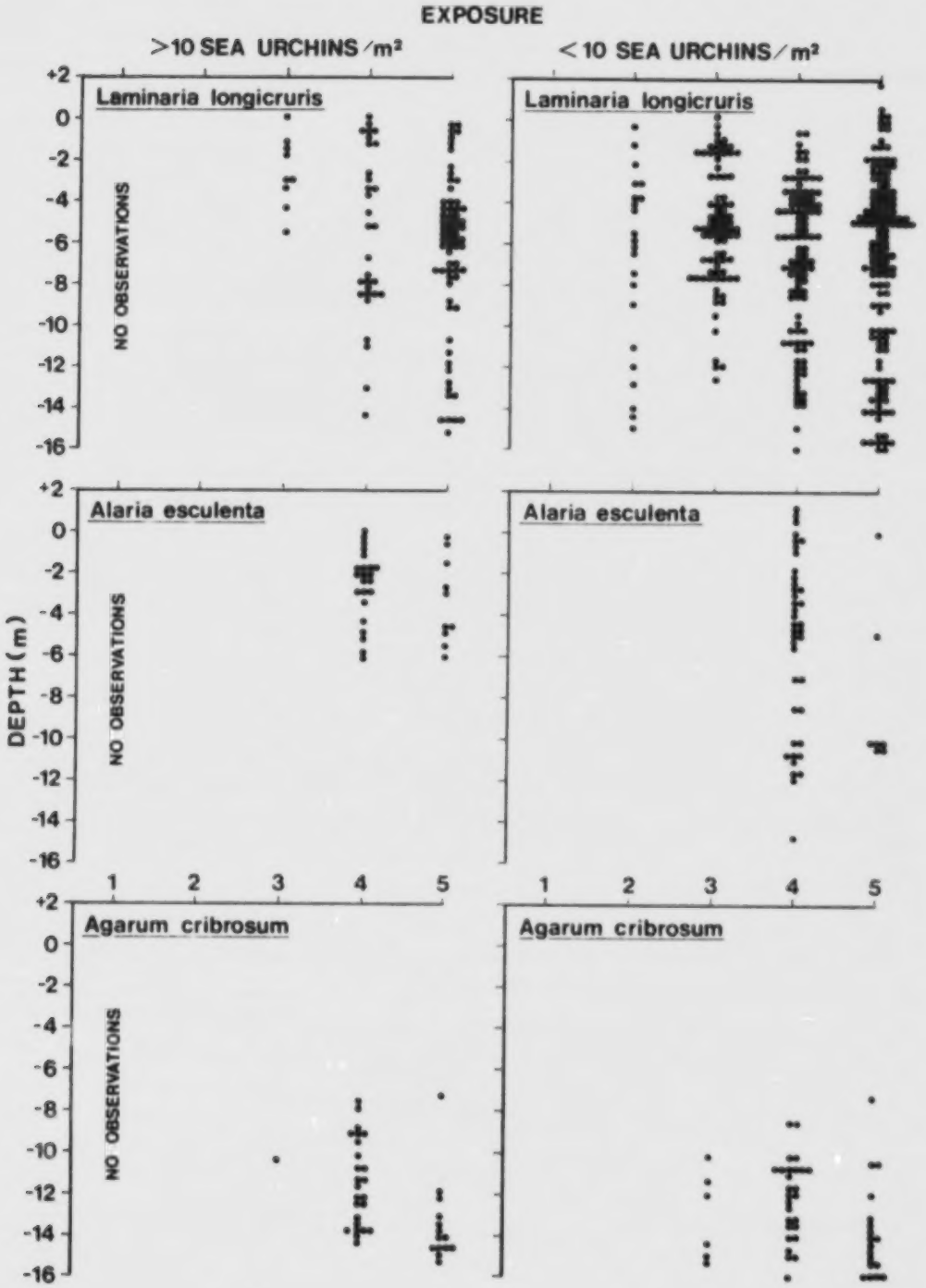

Figure 6. Frequency of occurrence of seaweed taxa by depth and exposure. Each dot represents presence of the alga at one station.

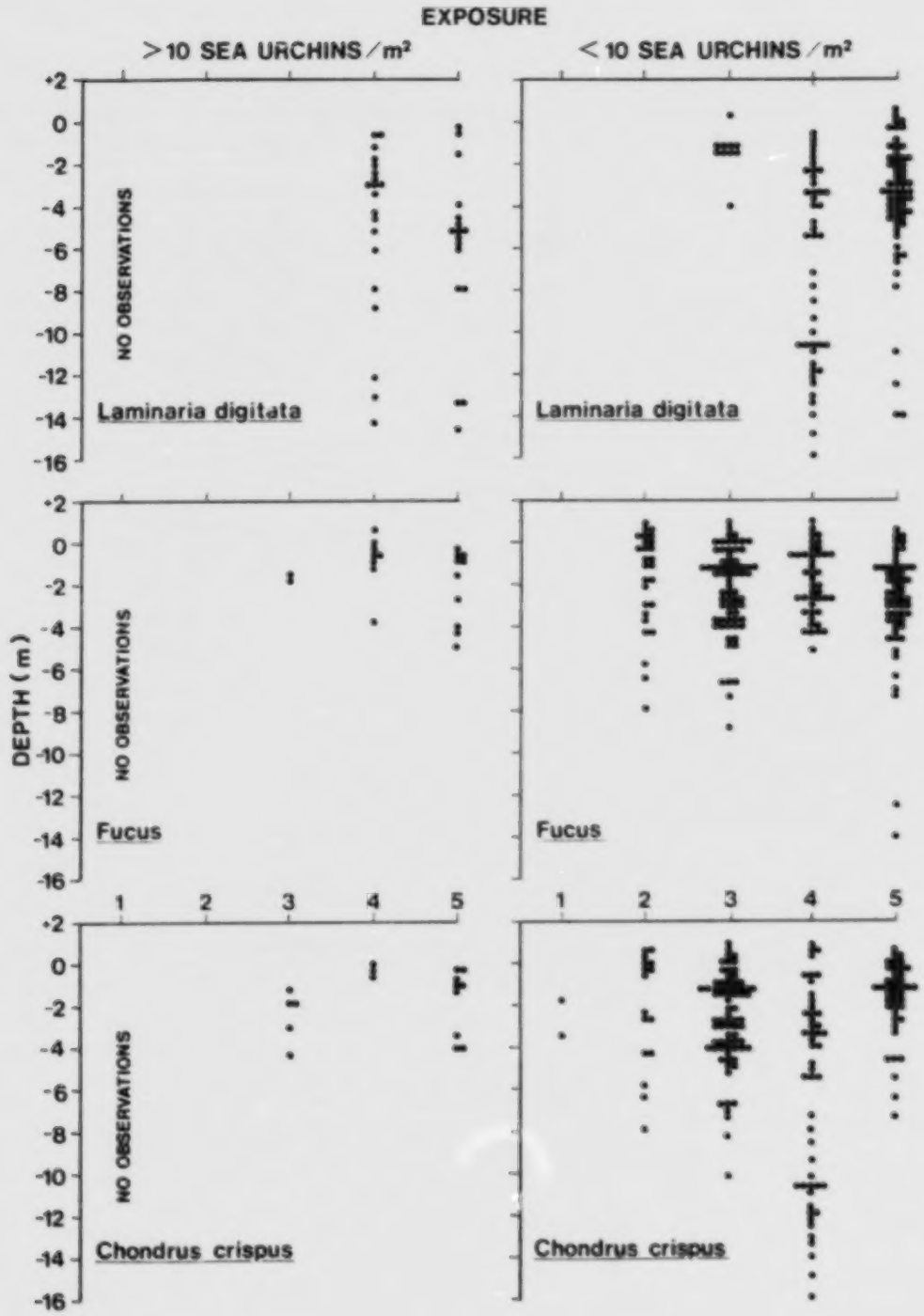

Figure 6. (cont'd)

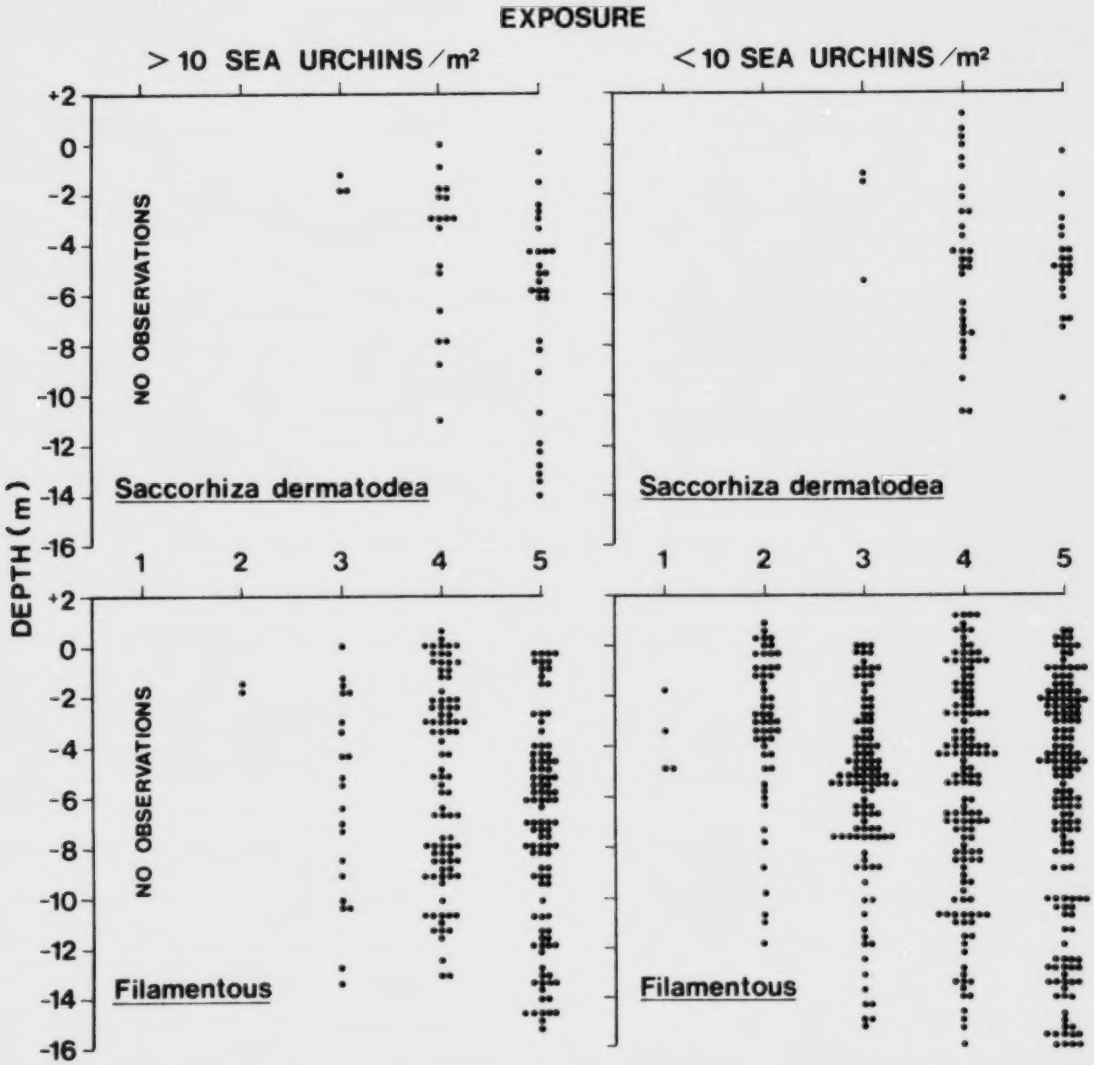

Figure 6. (cont'd)

Fucus spp. and C. crispus occurred more frequently and kelps less frequently in Region 3 than in Regions 1 or 2. Fucus was rarely encountered in Region 1, but occurred at 47% of the station in Region 3. The occurrence of Chondrus increased from 13% in Region 1 to 39% in Region 3. Among the kelps, A. esculenta was not found in Region 3, and L. digitata and S. dermatodea occurred over four times as frequently in Region 1 as in Region 3.

DISCUSSION

PHYSICAL HABITAT

The physical characteristics of the present survey area were similar to those of the previously surveyed area to the southwest. Approximately half of the shoreline was "rocky" in both surveys, and the percentages of the rocky habitat located on the open coast (Exposures 4 and 5) were 82% and 81% in the first and second surveys respectively. The average width of rocky habitat was 370 m and 360 m in the two surveys. An 80 km segment, from Mira Bay to Big Bras D'Or Channel, was the only sandstone found on the coast. Sandstone's friable quality makes it a poor substrate for kelps in shallow water (Bell and MacFarlane 1933b; Bird et al. 1983).

Summer temperatures, measured as degree days above 0°C from mid-May to mid-October, were 20-25% higher in eastern Cape Breton than on the south coast of Cape Breton or on the eastern shore (Table 4). The difference results from warm surface waters exiting the Gulf of St. Lawrence in a 50 m thick layer along the eastern Cape Breton coast (El-Sabh 1980). The warm layer mixes with cooler oceanic water upwelling near Scatarie Island and flows southwest along the Cape Breton coast and eastern shore (Dadswell 1979).

The relevance of the temperature regimes to the development of lobster larvae is discussed in Appendix 2.

SEAWEEDS

Van den Hoek (1982) described "southern lethal boundaries" as locations where the average temperature for the warmest month exceeds a critical value. The critical temperature of 19°C for L. digitata and L. longicruris was not exceeded in any of the habitats surveyed, and these species were present in all regions, although their prevalence was reduced at stations on the east coast of Cape Breton where the highest monthly mean temperature was 18°C. Van den Hoek's southern lethal boundary for S. dermatodea was 15°C, but this species was found in all regions even though all regions exceeded this temperature.

C. crispus, a slow-to-colonize species (Lubchenko 1980), was found well within its temperature limits (Mathieson and Prince 1973) in all regions. Its greater prevalence at stations in eastern Cape Breton may be due to a longer period free of urchin grazing.

A. esculenta was common in Regions 1 and 2, but it was not found at any of the stations in Region 3 (Table 9). Bell and MacFarlane (1933a) reported that A. esculenta was abundant along the Atlantic coast of Nova Scotia and absent in the southern Gulf of St. Lawrence which is adjacent to Region 3. Since Region 3 water temperatures (Ingonish) were similar to those of the southern Gulf (Magdalen Islands), the absence of Alaria in Region 3 may be temperature related.

Fucus spp. was most prevalent in Region 3 and least prevalent in Region 1, but our data do not suggest an explanation.

Prior to 1980 most of the shallow, rocky bottom between Cape Sable Island and Scatarie Island was sea urchin-dominated barrens. In 1979 Wharton and Mann (1981) surveyed seven sites at 10 m depth between Cape Sable Island and Dover, just west of Chedabucto Bay. All were urchin dominated, with less than 20% plant cover. Surveys from Cape Sable Island to Ship Harbour during 1980-82 (Miller and Colodey 1983; Moore and Miller 1983) showed that seaweed was sparse and urchins abundant; urchin mass mortalities began in the autumn of 1980. Seaweed refuge areas comprised no more than 10% of the habitat (Miller 1985a). We did not systematically survey from Ship Harbour to Chedabucto Bay prior to 1984, by which time seaweed was recovering following mass mortalities of urchins; but from results of Wharton and Mann (1981), our spot diving surveys (Miller and Colodey 1983), fishermen interviews (Miller 1985a), and aerial surveys noting quantities of dead urchins on the beach (Miller and Colodey 1983; Moore and Miller 1983), we conclude that the area had been recently sea urchin dominated. The present survey showed that most of the remaining area, from the west side of Chedabucto Bay to Scatarie Island, was still urchin dominated in 1984.

SEA URCHINS

Sea urchins were most prevalent in exposed areas (Exposures 3-5) and moderate depths (5-10 m). The few urchins present in sheltered areas tended to be in 0 to 5 m depths.

Incidental observations indicate that sea urchin mortalities are continuing on a wide front. Piles of urchin tests, indicating recent (<1 yr) urchin mortalities, were observed on Transects 38 and 50. During September 1984 urchin tests washed ashore on a beach at Wine Harbour, near Transect 13. Mortalities were reported in the autumn of 1985 on the west side of Chedabucto Bay (Nils Hagen, Dalhousie University, Halifax, N.S., pers. comm.), at the mouth of Louisbourg Harbour, and around Scatarie Island (Patrick Young, Dobrocky-Seatech Consultants, Dartmouth, N.S., pers. comm.).

Based on surveys from 1980-1983, 245,000 t of urchins died between Cape Sable Island and Ship Harbour (Miller 1985). Adding the 25,000 t between Ship Harbour and County Harbour as determined in this study brings the total mass mortality to 270,000 t during 1980-1985.

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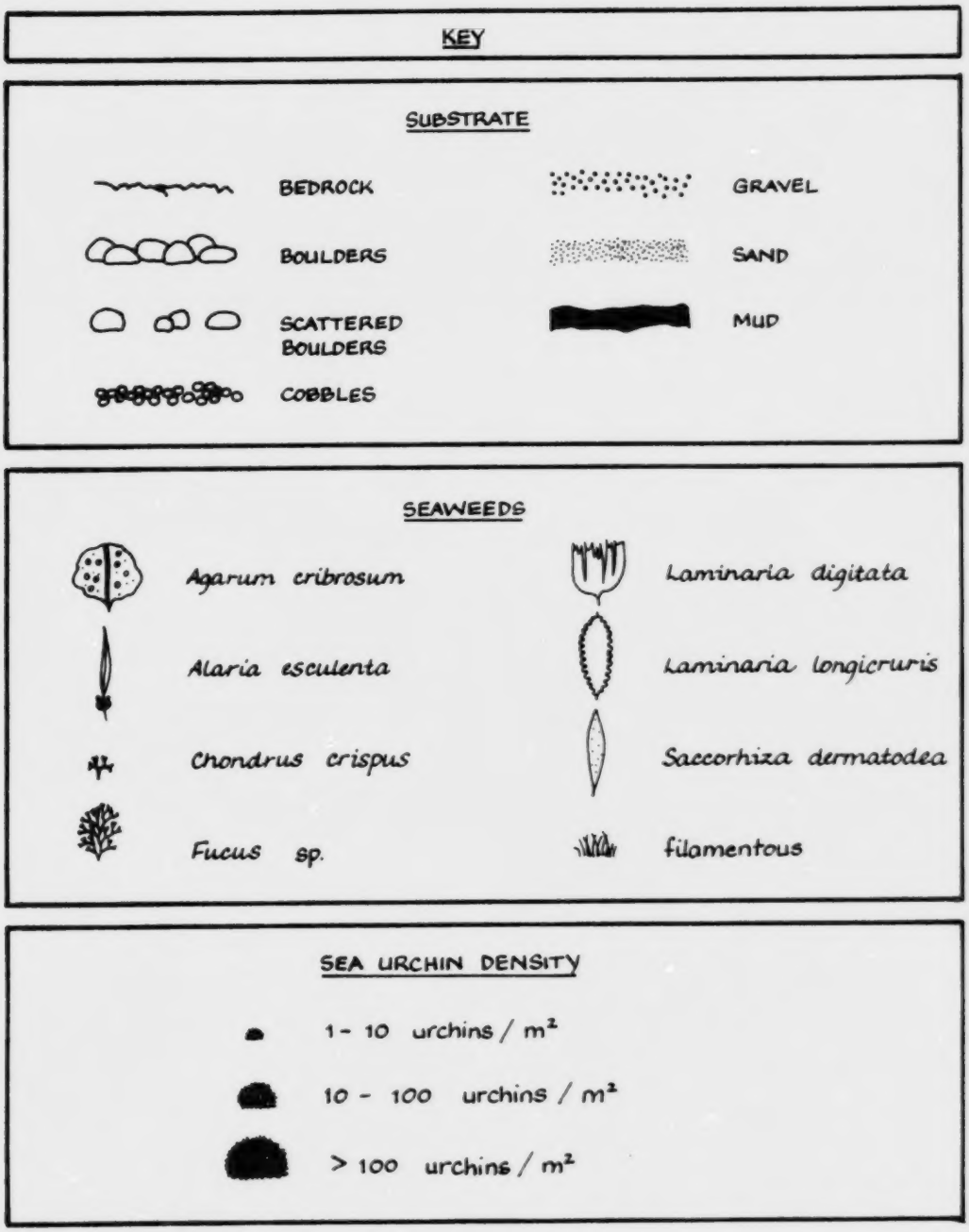
Appendix 1 Transect profiles



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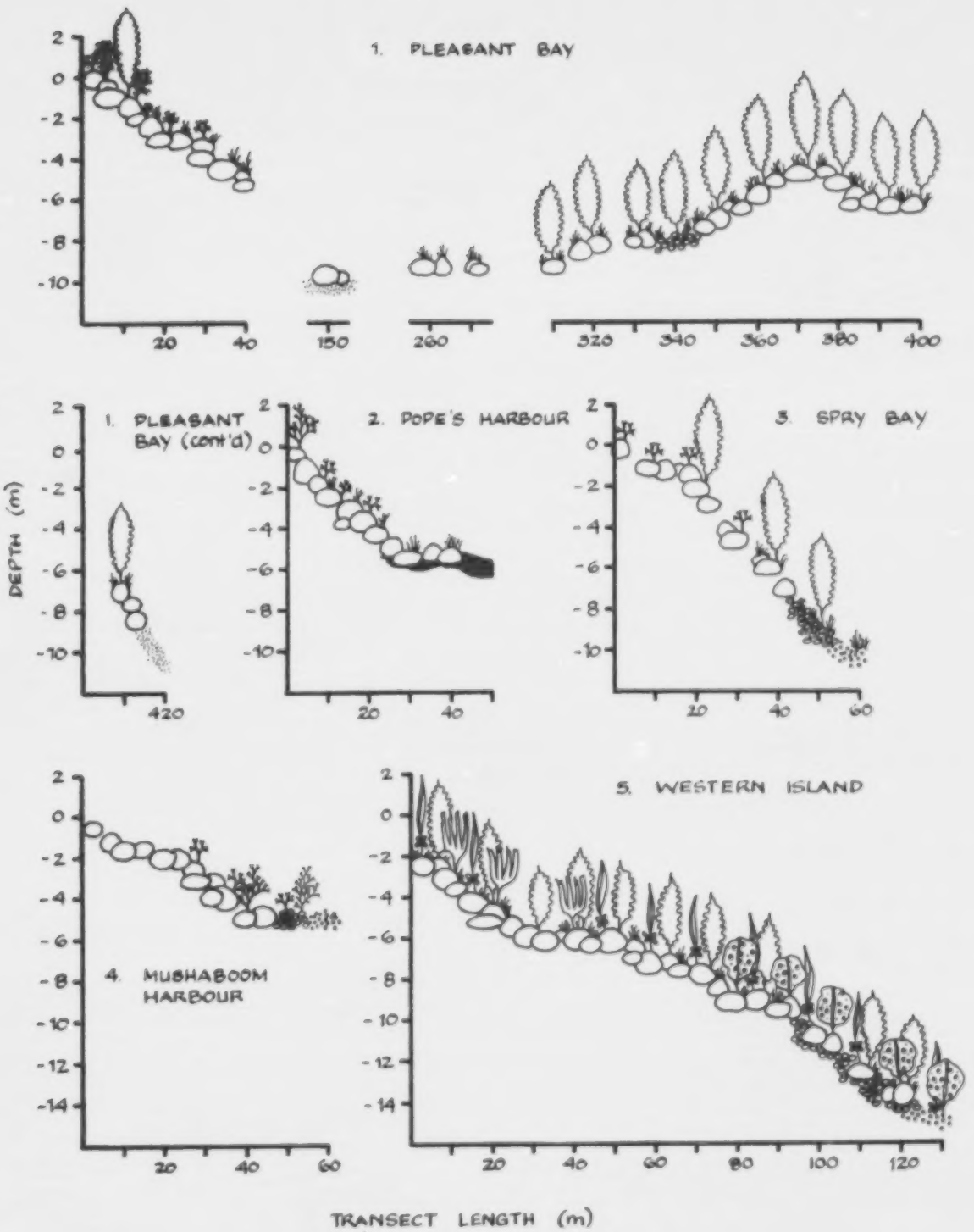

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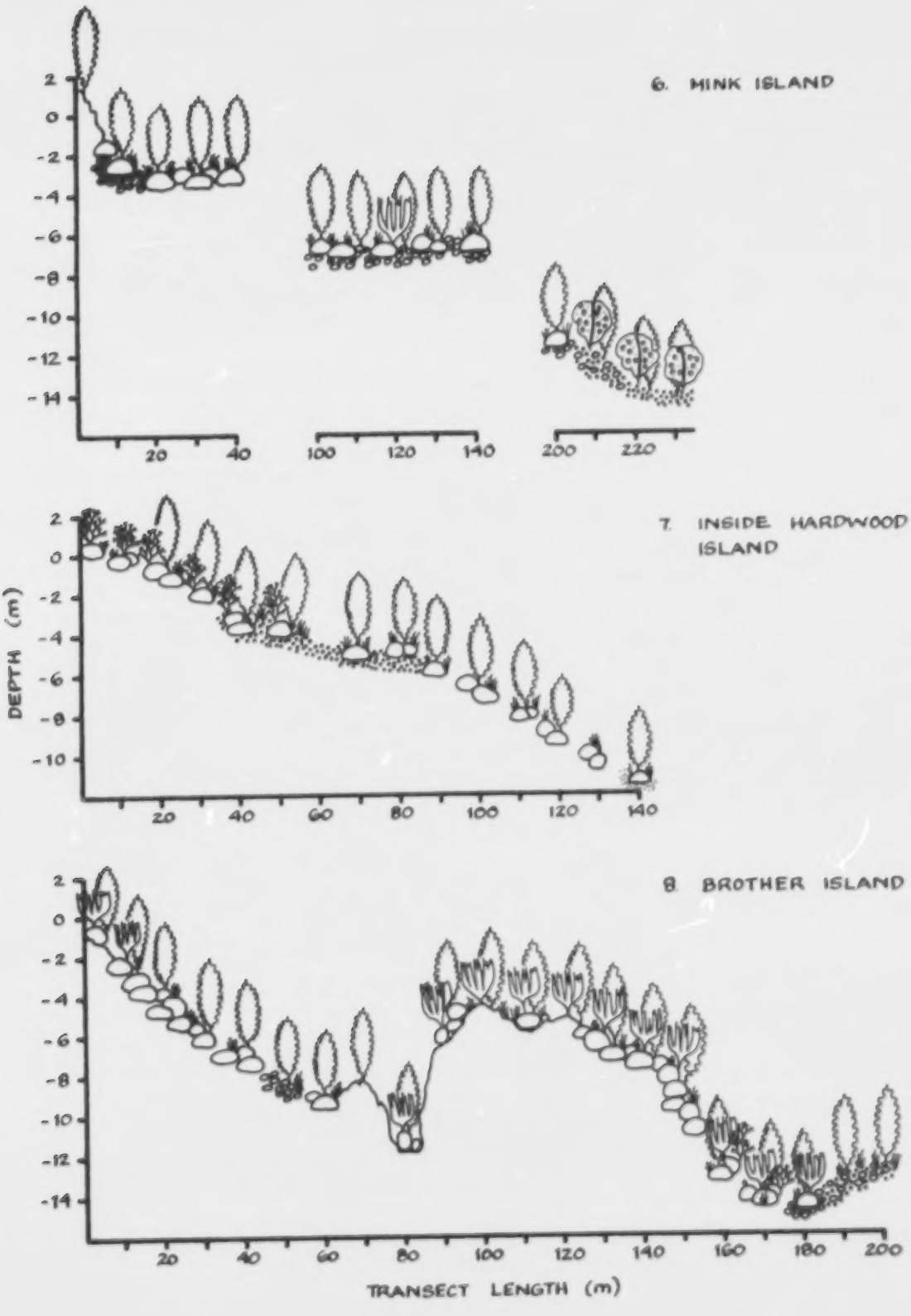

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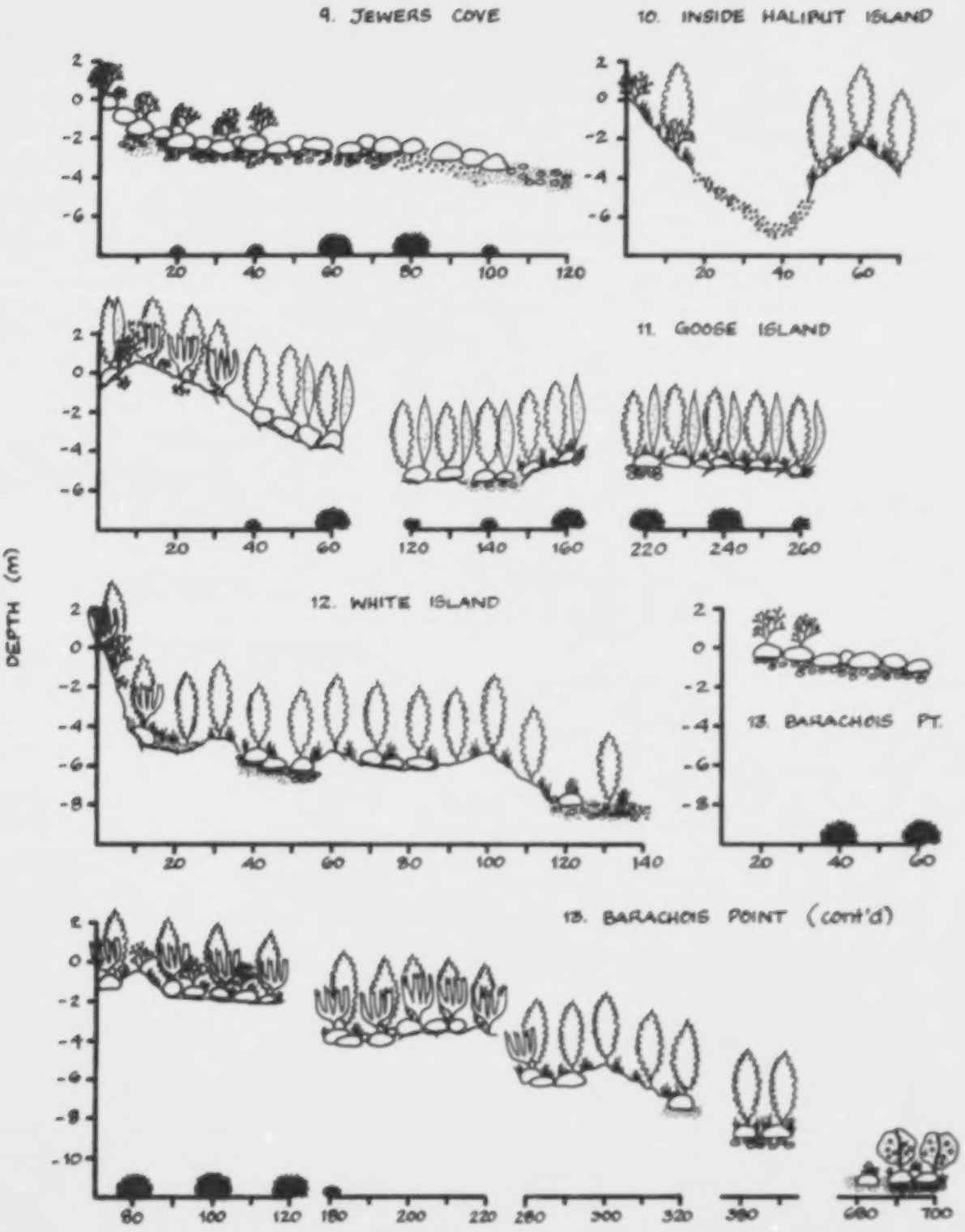

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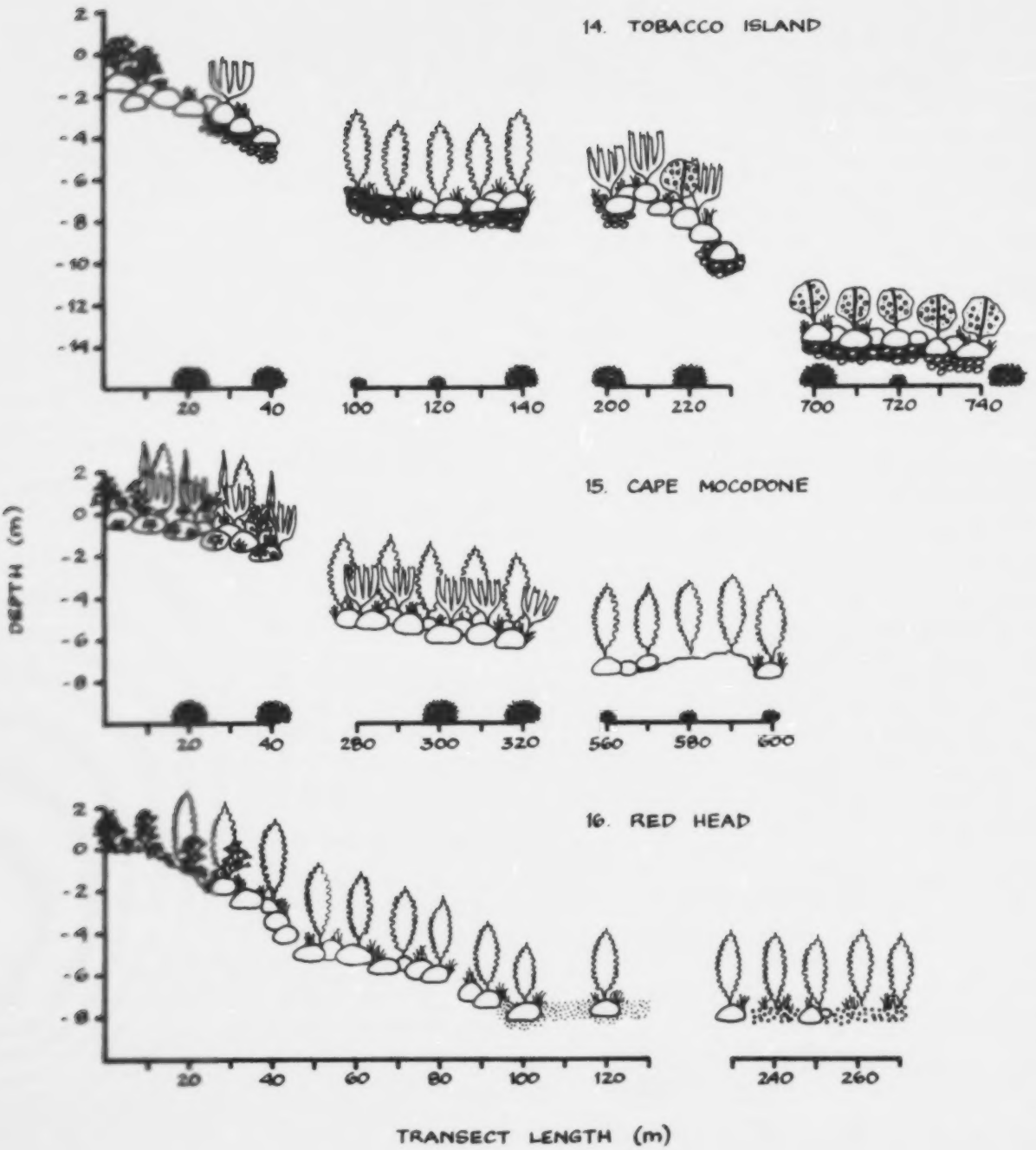

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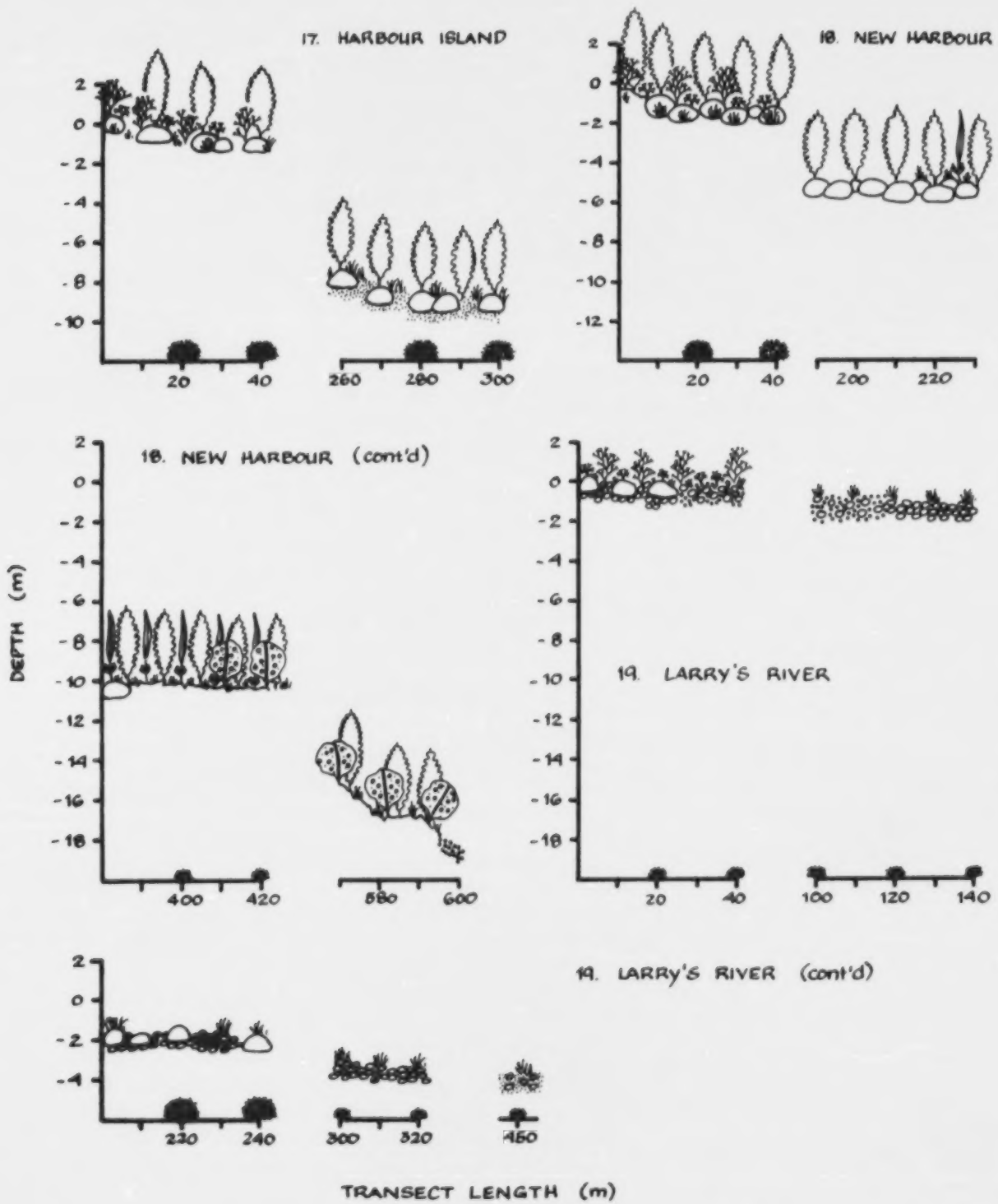

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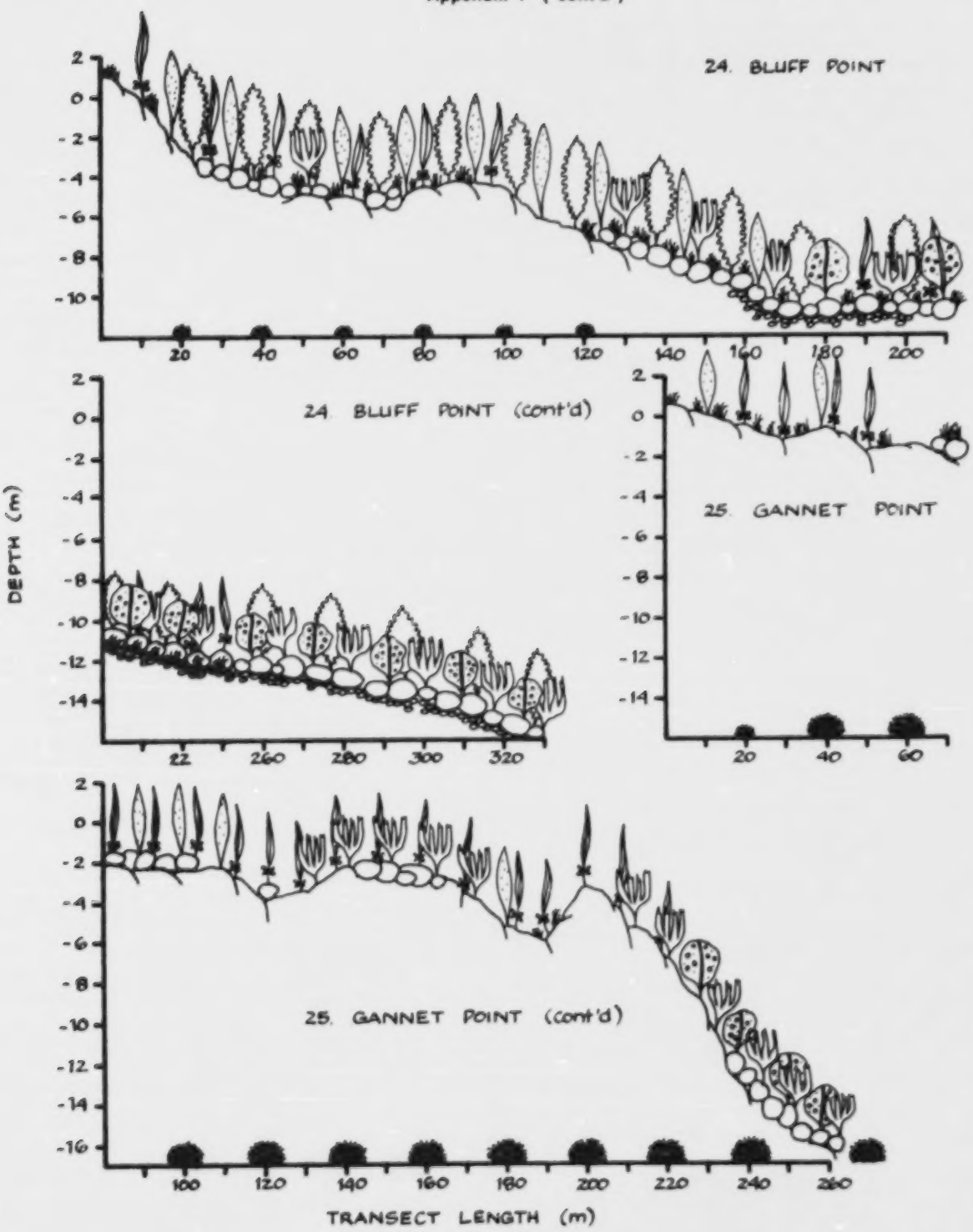

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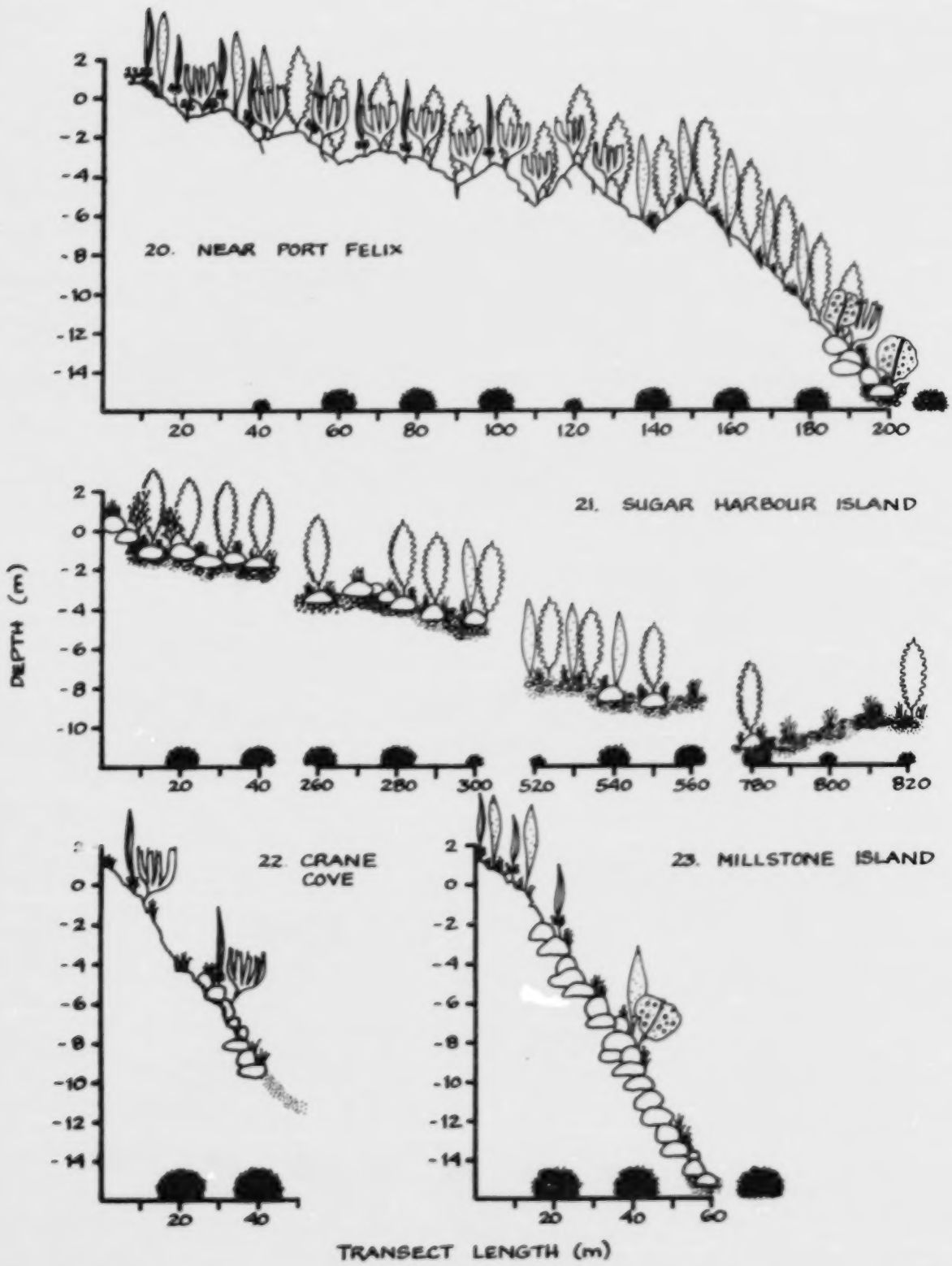

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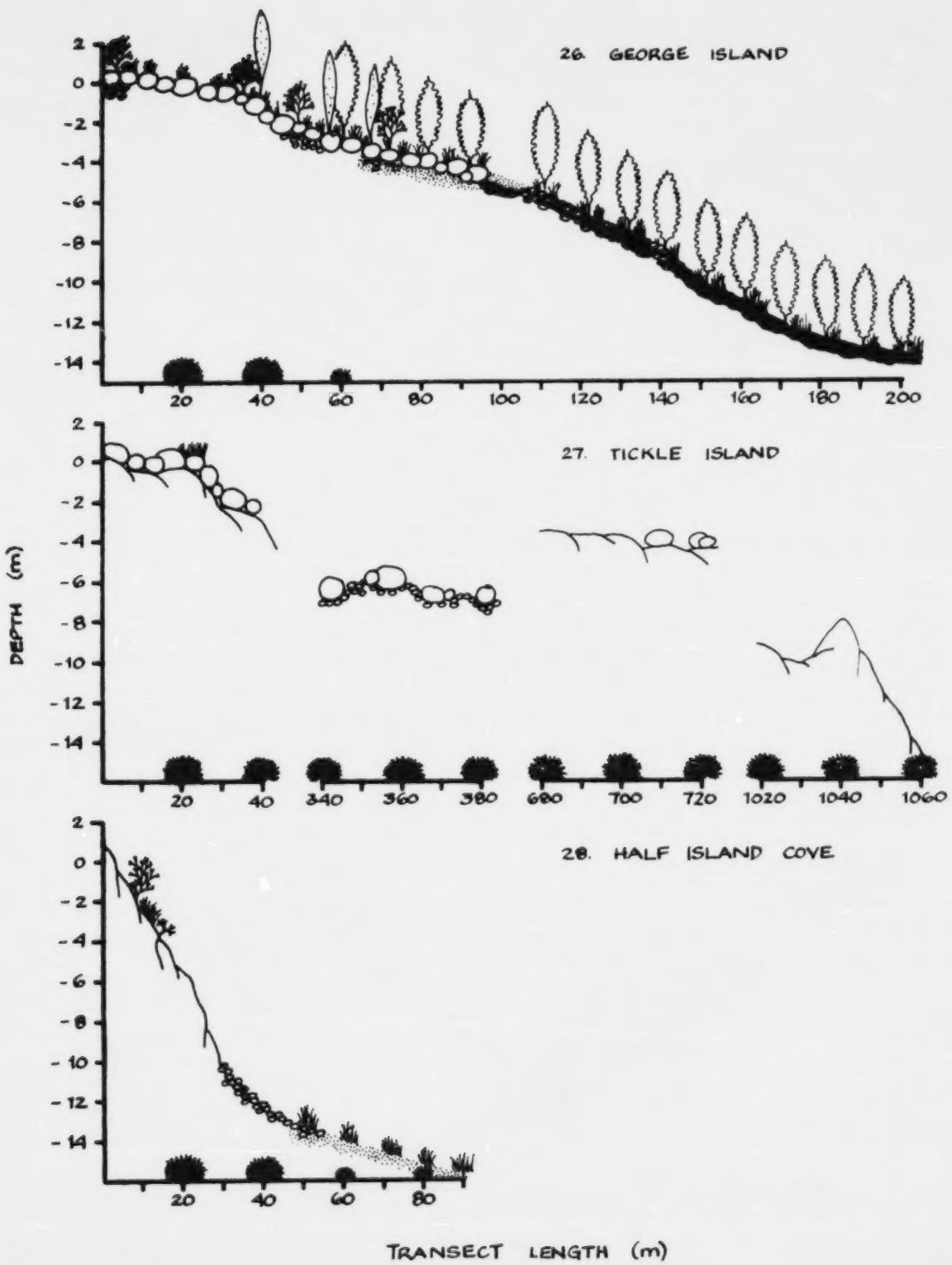

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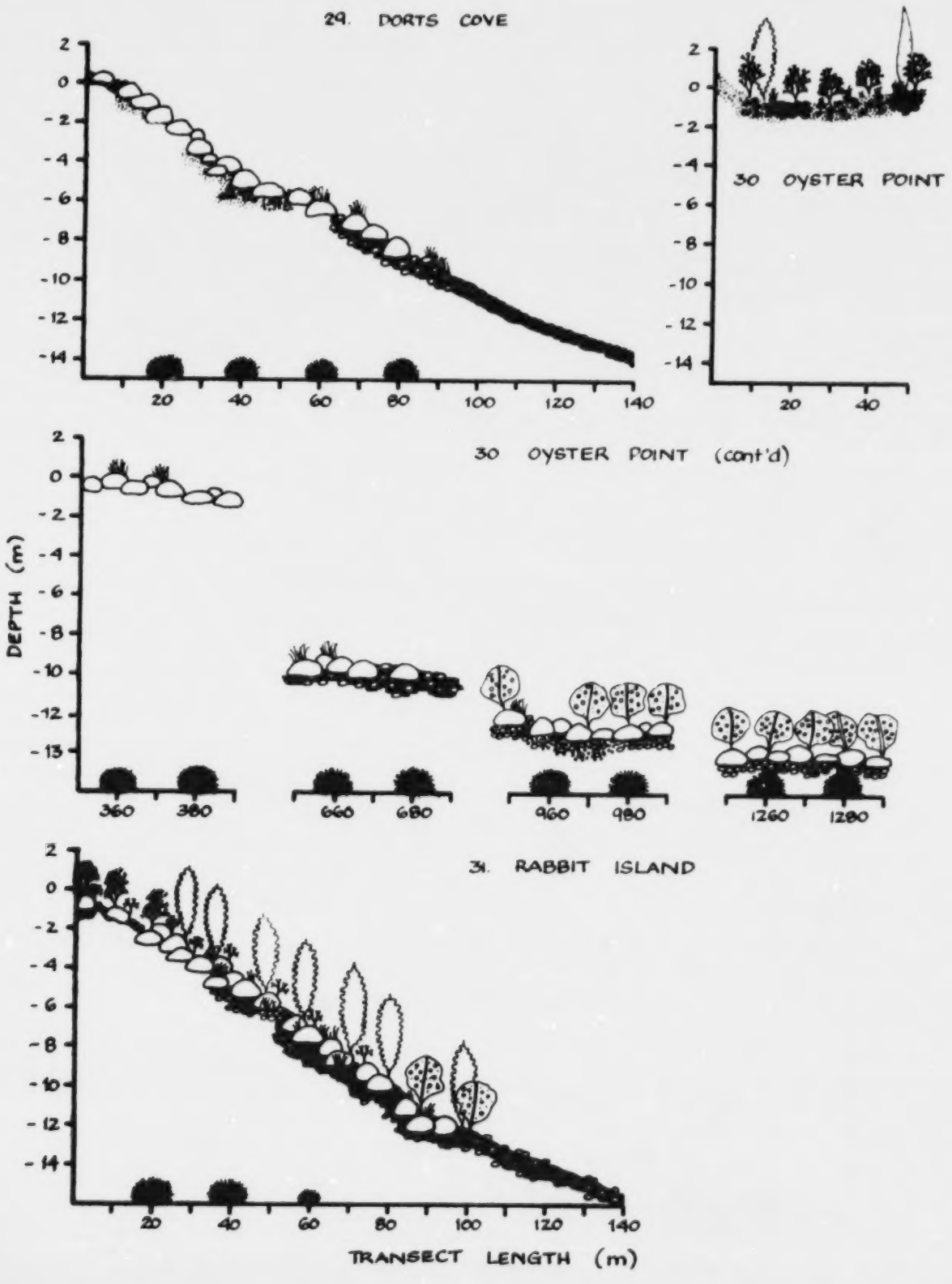

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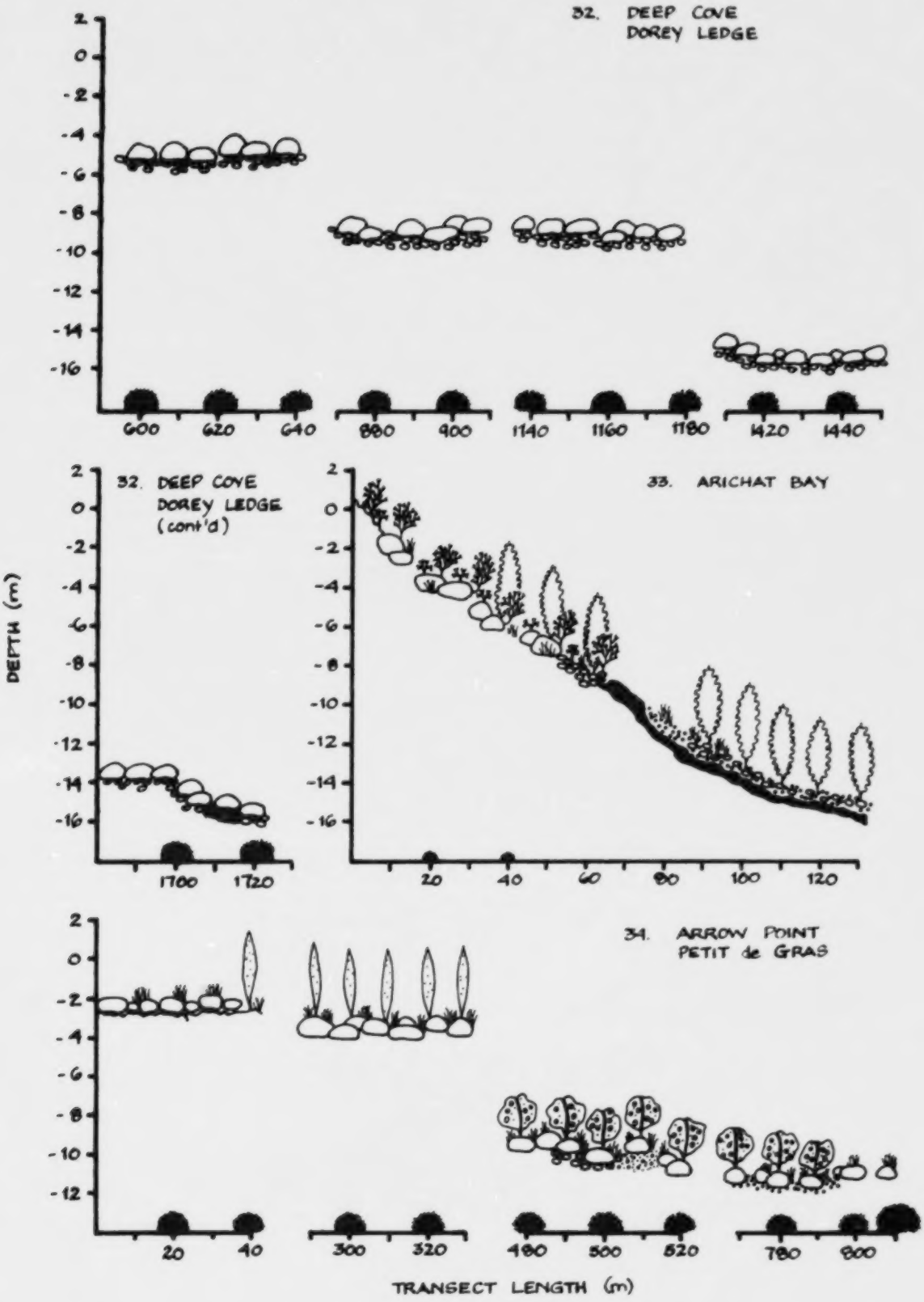

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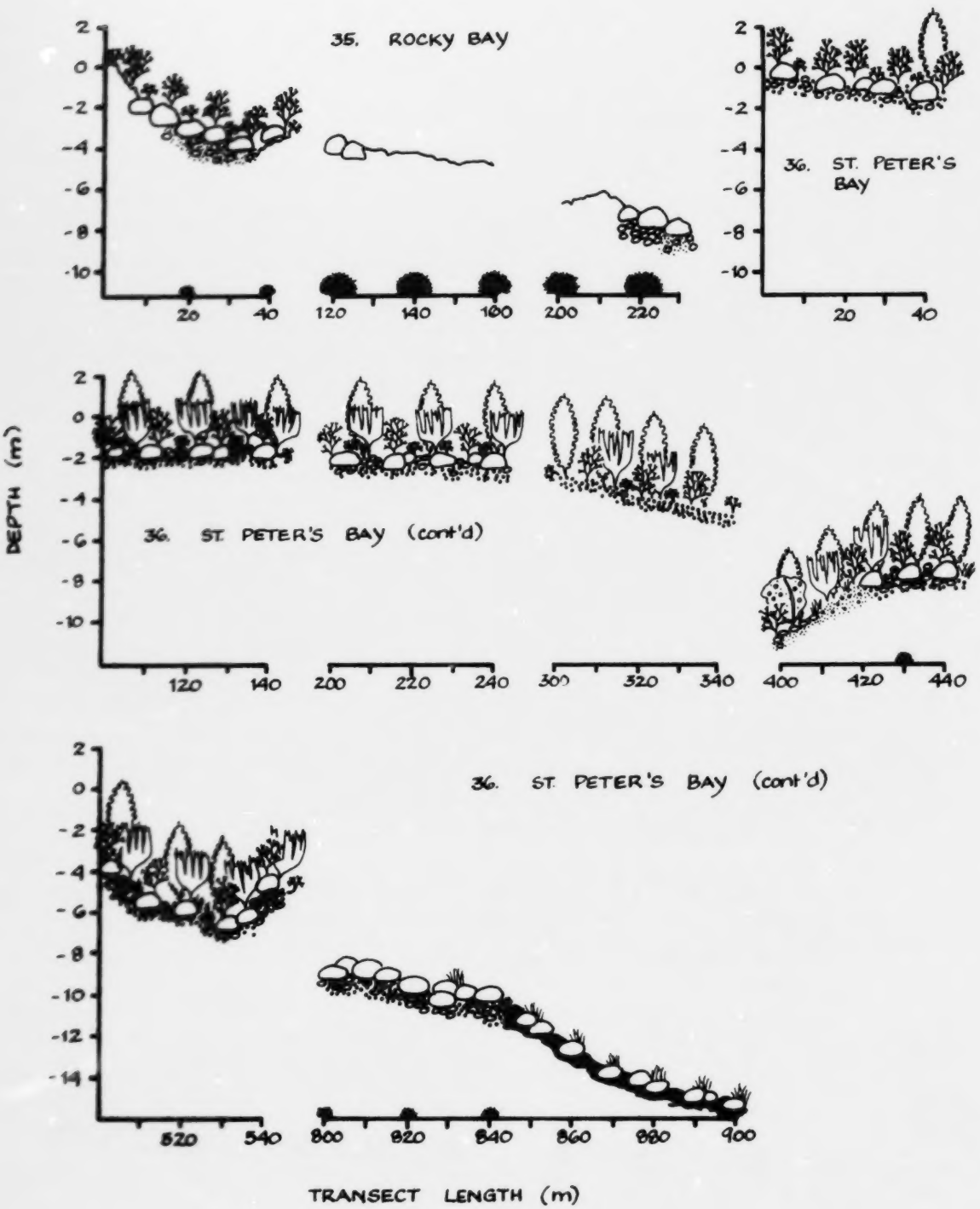

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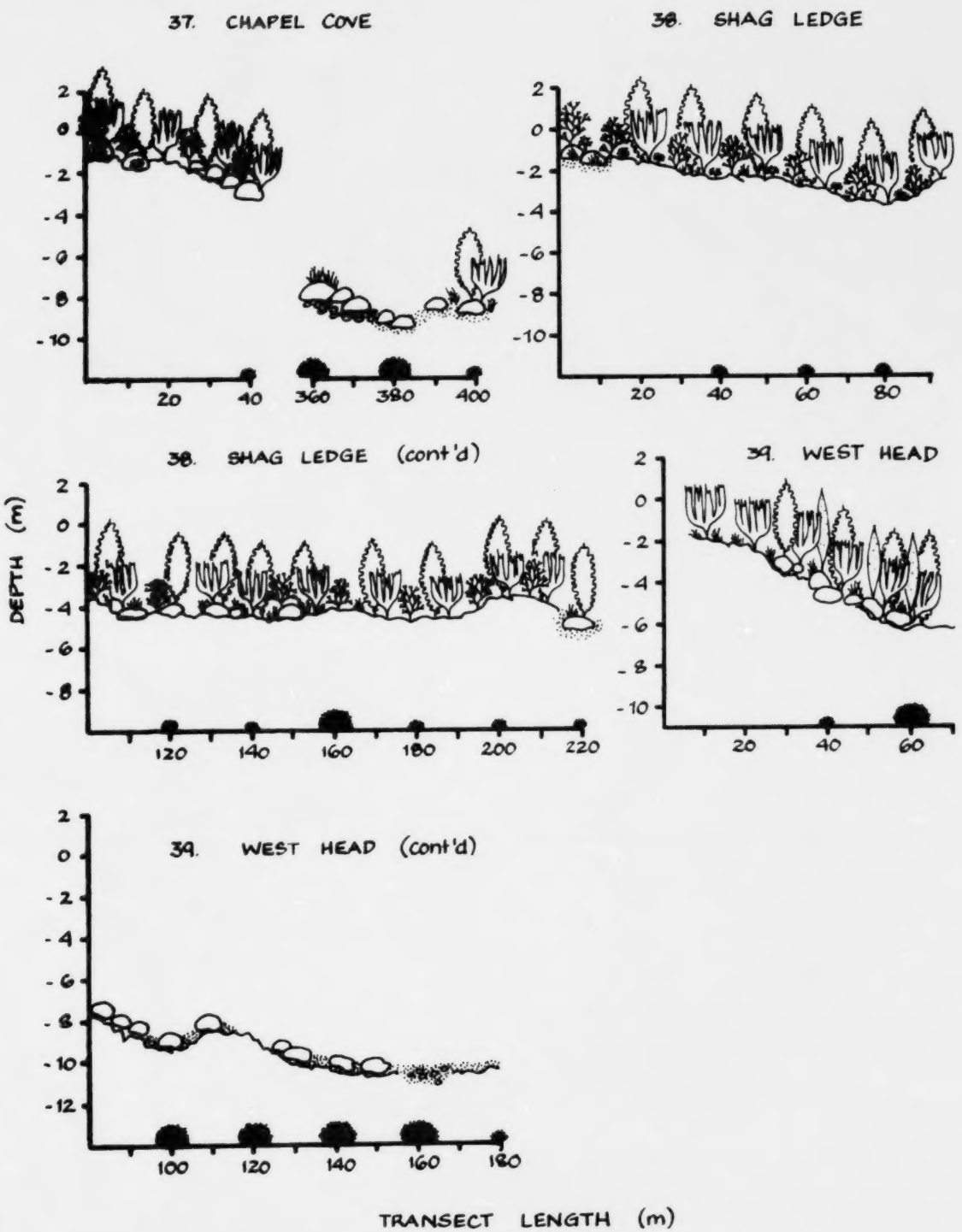

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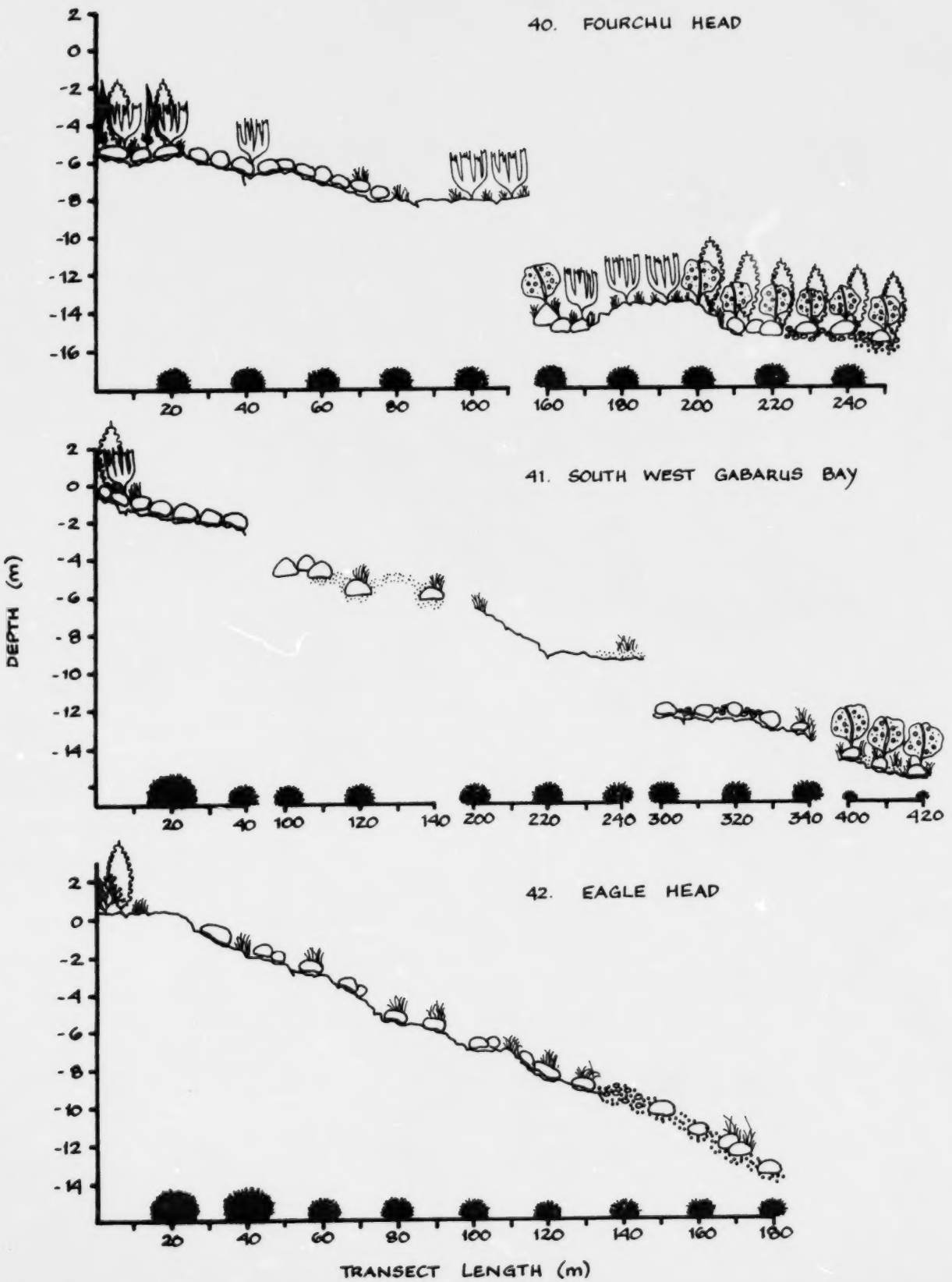

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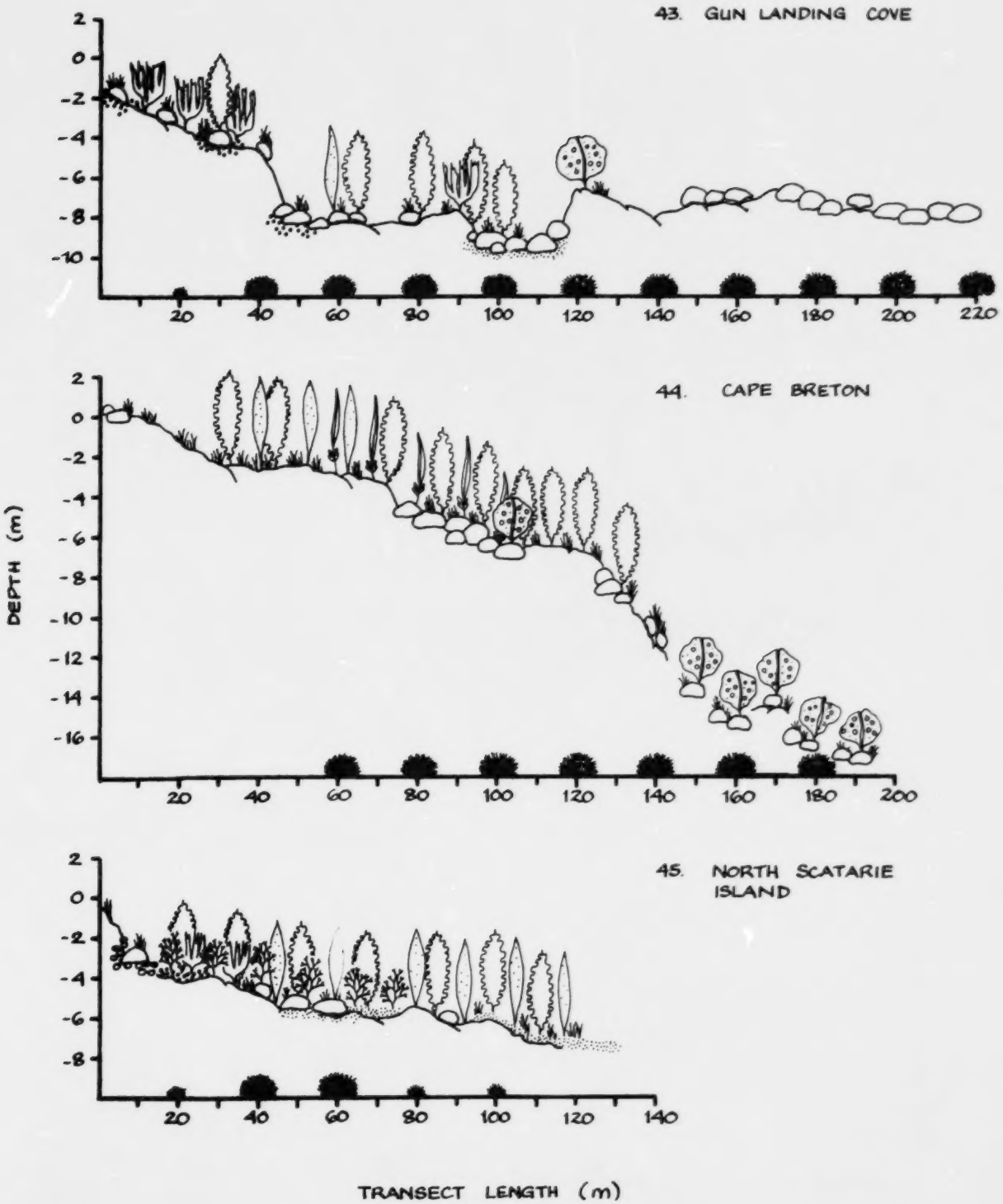

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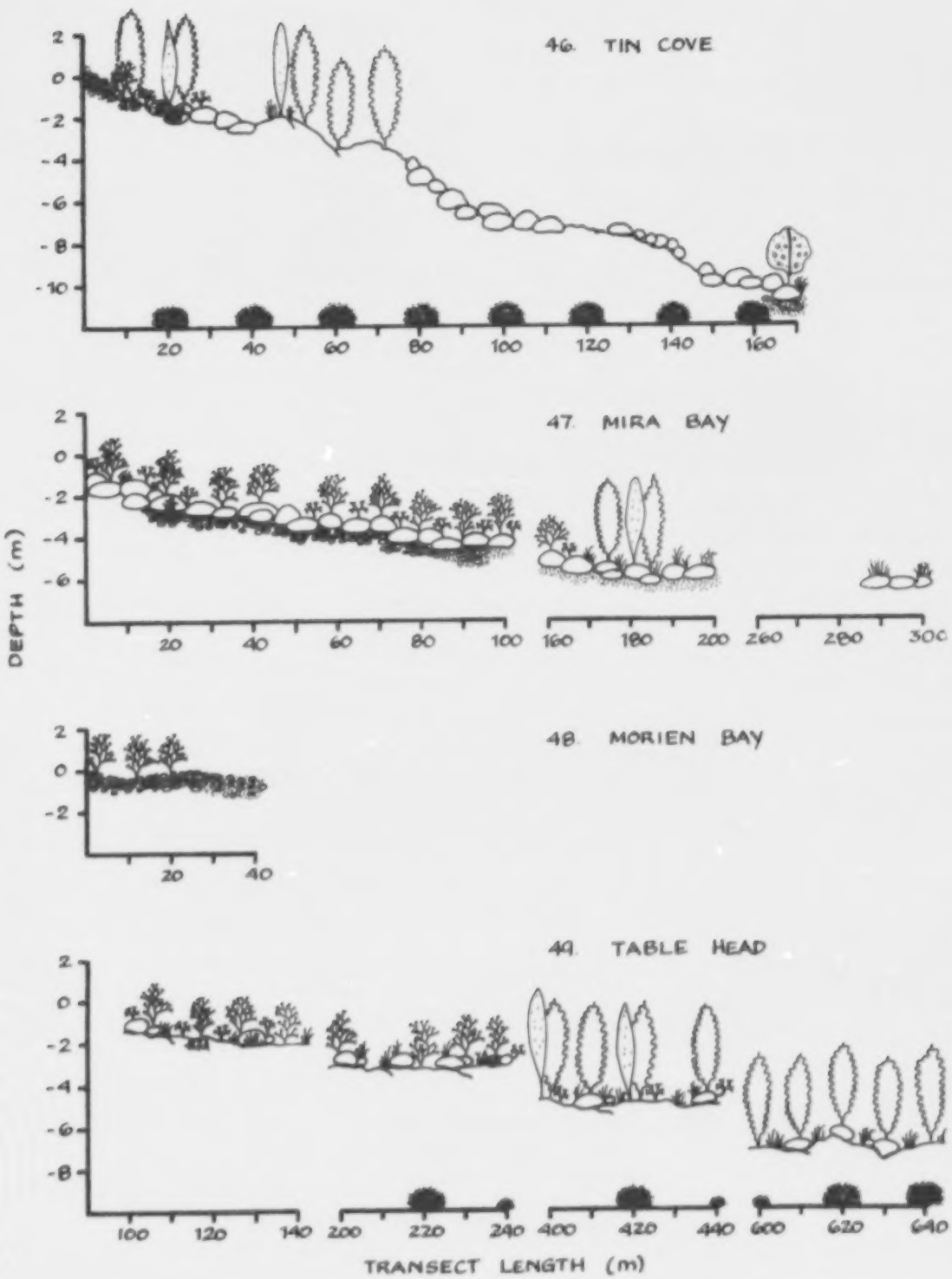

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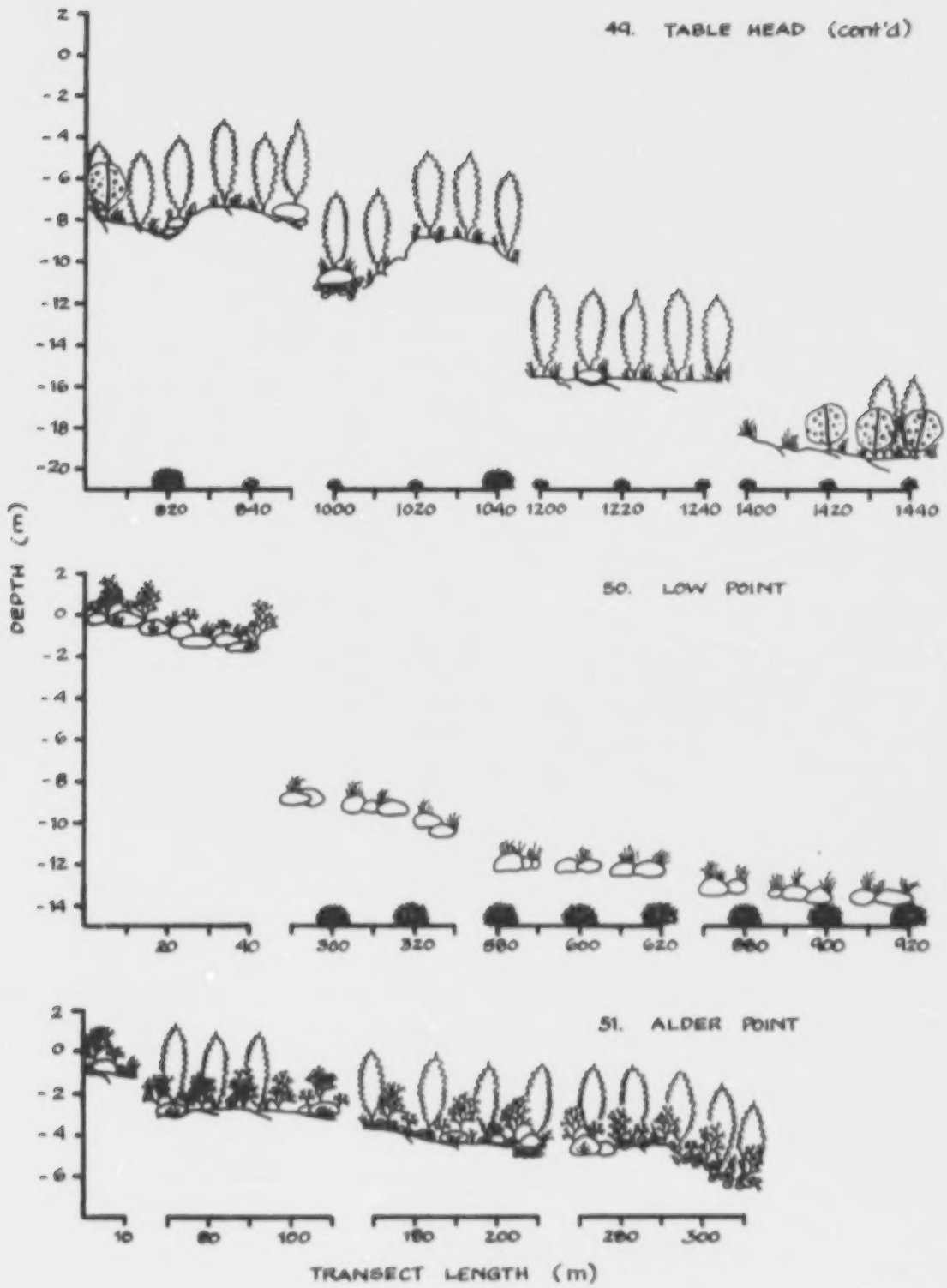

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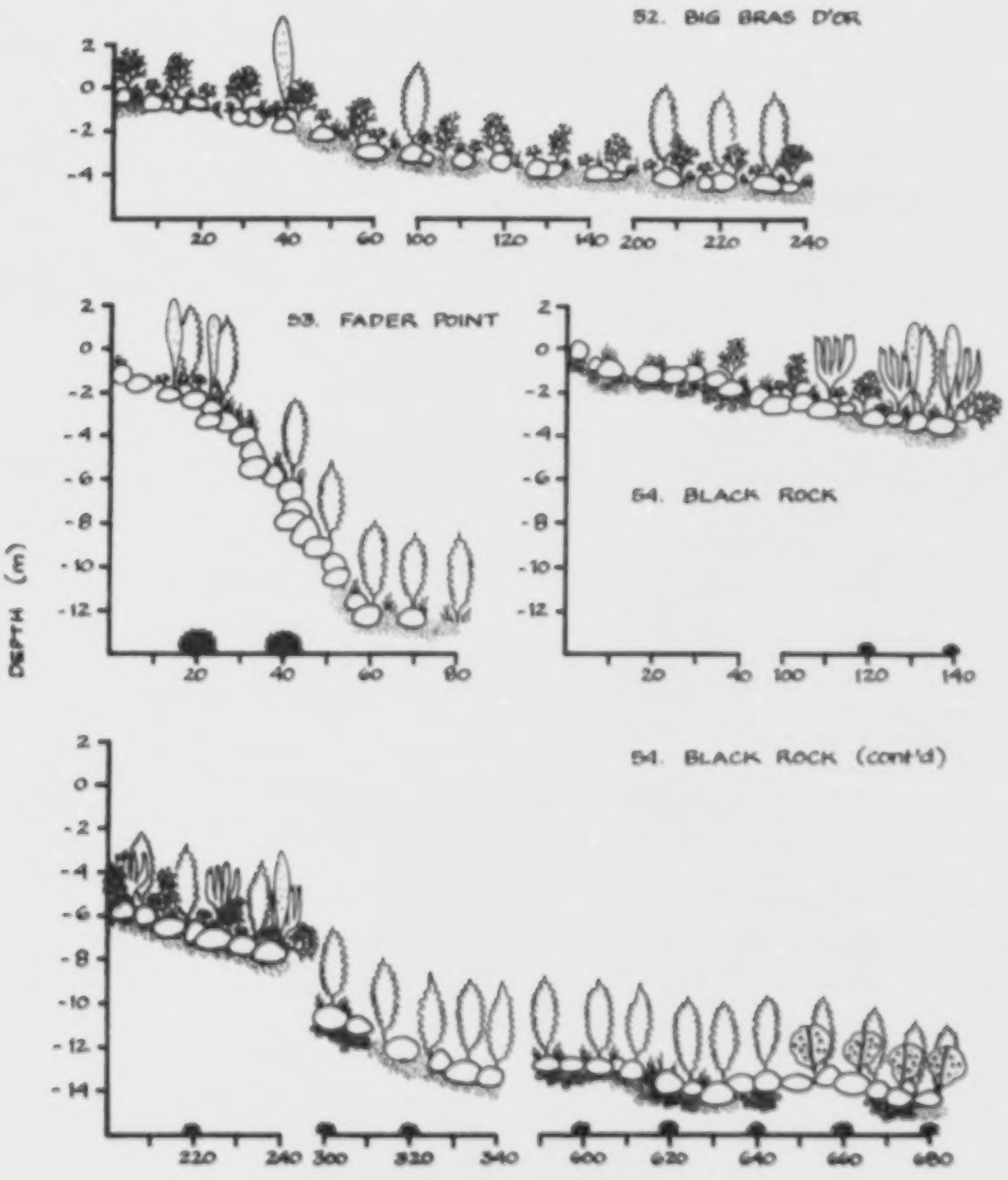

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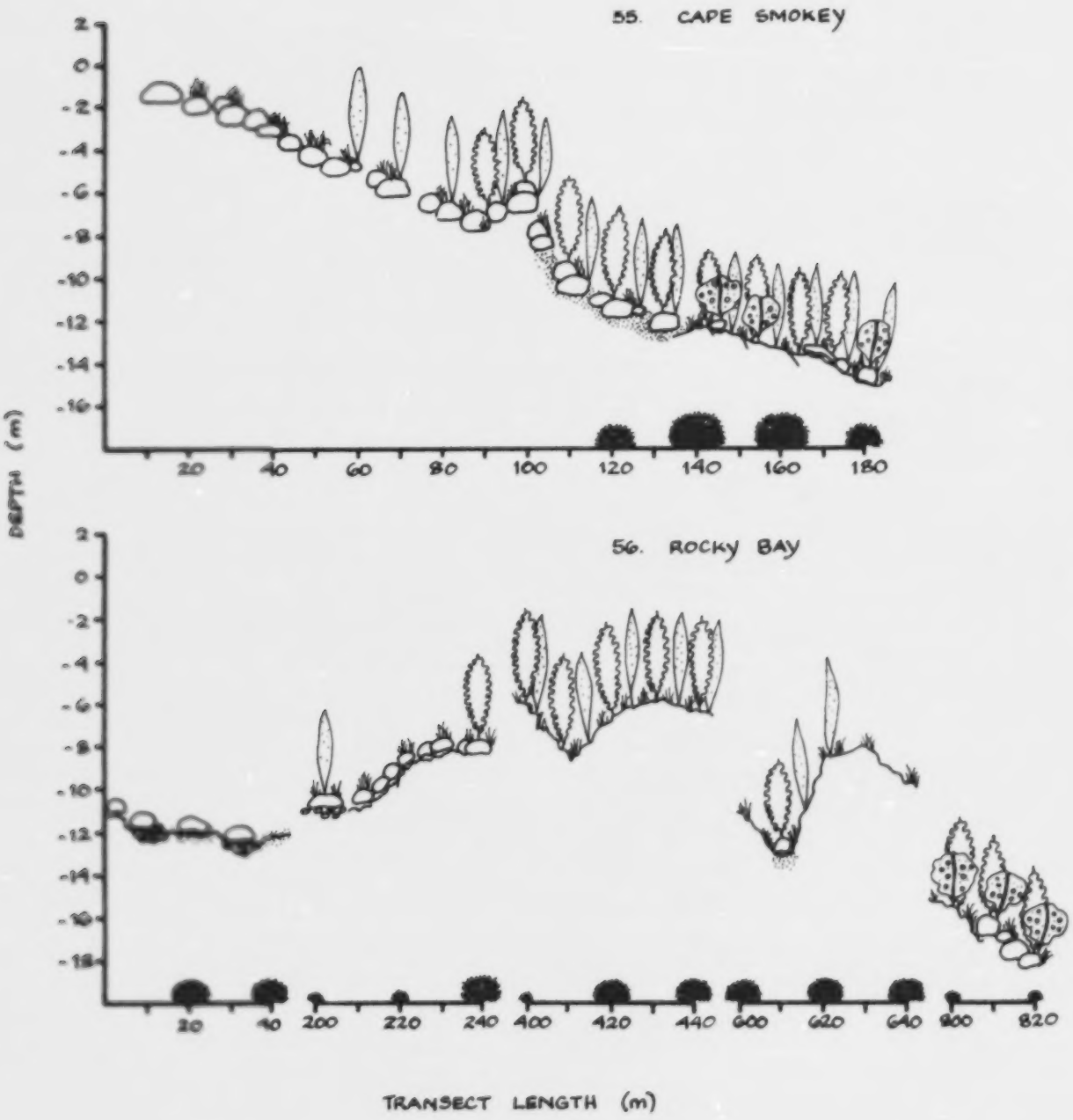

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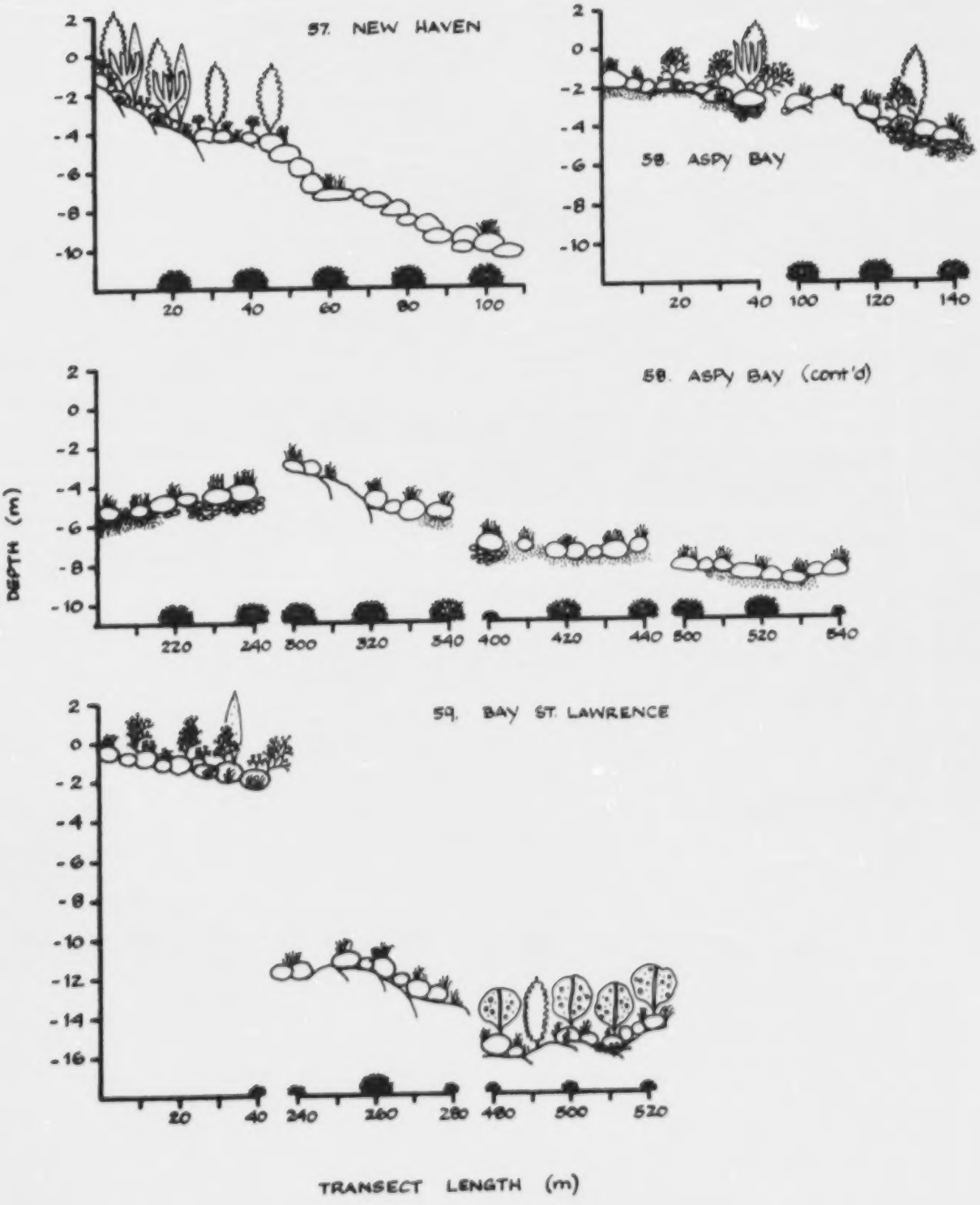


APPENDIX 2

DEVELOPMENT OF LOBSTER LARVAE

Harding et al (1983) suggested that low temperatures made the Atlantic Coast of Nova Scotia a marginal area for the development of lobster larvae, and hence for recruitment. However, the temperature-dependent development rates combined with the 1984 temperature regimes at the five thermograph sites indicate that temperatures were high enough for complete larval development at all sites (Table A2.1). For example, at Little Harbour if larvae hatched on calendar day 220, when the temperature first reached 12.5°C, development would have been complete by day 250. Larvae could have hatched as late as day 241 and completed development before the temperature dropped below 10°C on day 280. Complete development could have occurred up to 1.7 times at the coldest site and 3.1 times at the warmest site.

Table A2.1. Predicted development rates of lobster at five thermograph sites in 1984.

A. Fraction of larval development, from hatching to mid-Stage 4, occurring in 1 d, based on Templeman (1936).

Temperature (°C)	Fraction/day	Temperature	Fraction/day
20	0.055	14	0.025
19	0.050	13	0.022
18	0.043	12	0.019
17	0.036	11	0.015
16	0.032	10	0.012
15	0.029		

B. Predicted number of larval development cycles assuming larvae first hatch at 12.5°C and stop developing below 10°C (Harding et al. 1983), using 1984 temperatures (Dobson and Petrie 1985; and Fig. 3), and using the above development rates.

Location	Calendar day for: First hatch	Last hatch	Last complete development	Potential development cycles
Little Harbour	220	241	280	1.7
Port Bickerton	219	241	280	1.7
Canso	214	248	291	2.1
Gabarus	210	235	279	1.9
Ingonish and Murray Point	189	245	220	3.1

B

61°30'W

45°30'N

GUYSBOROUGH CO.

STRAIT OF CANSO

30 (1290m)

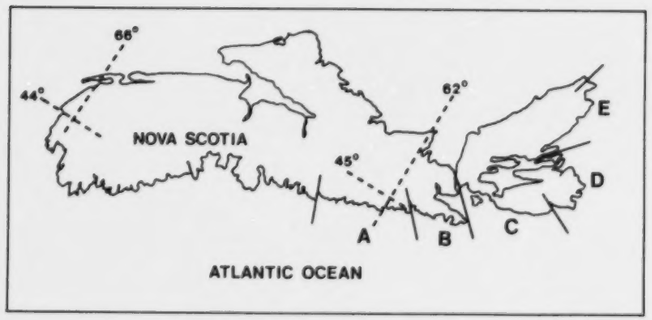
GUYSBOROUGH HBR.

CHEDABUCTO BAY

28 (90m)

29 (90m)

HALF ISLAND COVE



GUYSBOROUGH CO.

WHITEHAVEN HBR

TOR BAY

21 (820m)

22 (40m)

19 (450m)

20 (200m)

23 (60m)

COUNTRY HBR.

B

STRAIT OF CANSO

61°30'W

GUYSBOROUGH CO.

30(1290m)

GUYSBOROUGH HBR.

CHEDABUCTO BAY

28(90m)

27(1060m)

29(90m)

HALF ISLAND COVE

26(140m)

CANSO HBR.

GUYSBOROUGH CO.

62°

E

D

B

C

25(260m)

24 (340m) DOVER BAY

WHITEHAVEN HBR.

TOR BAY

21 (820m)

22(40m)

19(450m)

20(200m)

23(60m)

N

INDIAN

ATLANTIC OCEAN

A B C

TOR BAY

19(450m)

20(200m)

21 (820m)

22(40m)

23(60m)

COURTRY HBR.

ISAAC'S HBR.

16(250m

17 (300m)

NEW HARBOUR

18(590m)

HALIFAX CO.

GUYSBOROUGH CO.

ECUM SECUM

9 (120m)

NECUM TEUCH BAY

11(260m)

10(80m)

12(140m)

BAY OF ISLANDS

BEAVER HBR.

7 (140m)

SHEET HARBOUR

[A]

4 (60m)

3 (60m)

SPRY BAY

5(130m)

6(240m)

8(200m)

SHIP HARBOUR

TANGIER HARBOUR

1(220m)

2 (40m)

62°30'W

44°45'N

LITTLE HBR.

TOR BAY

21 (820m)

22(40m)

23(60m)

20(200m)

19(450m)

NEW HARBOUR

18(590m)

INDIAN HARBOUR

PORT. BICKERTON

15(600m)

ST. MARYS BAY

13(700m)

14 (310m)

LISCOMB HARBOUR

HALIFAX CO.

GUYSBOROUGH CO.

ECUM SECUM

61°45'W

45°00'N

9 (120m)

NECUM TEUCH BAY

11(260m)

10(80m)

12(140m)

BAY OF ISLANDS

BEAVER HBR.

7 (140m)

SHEET HARBOUR

6(240m)

(130m)

8(200m)

0

10 km

30'W

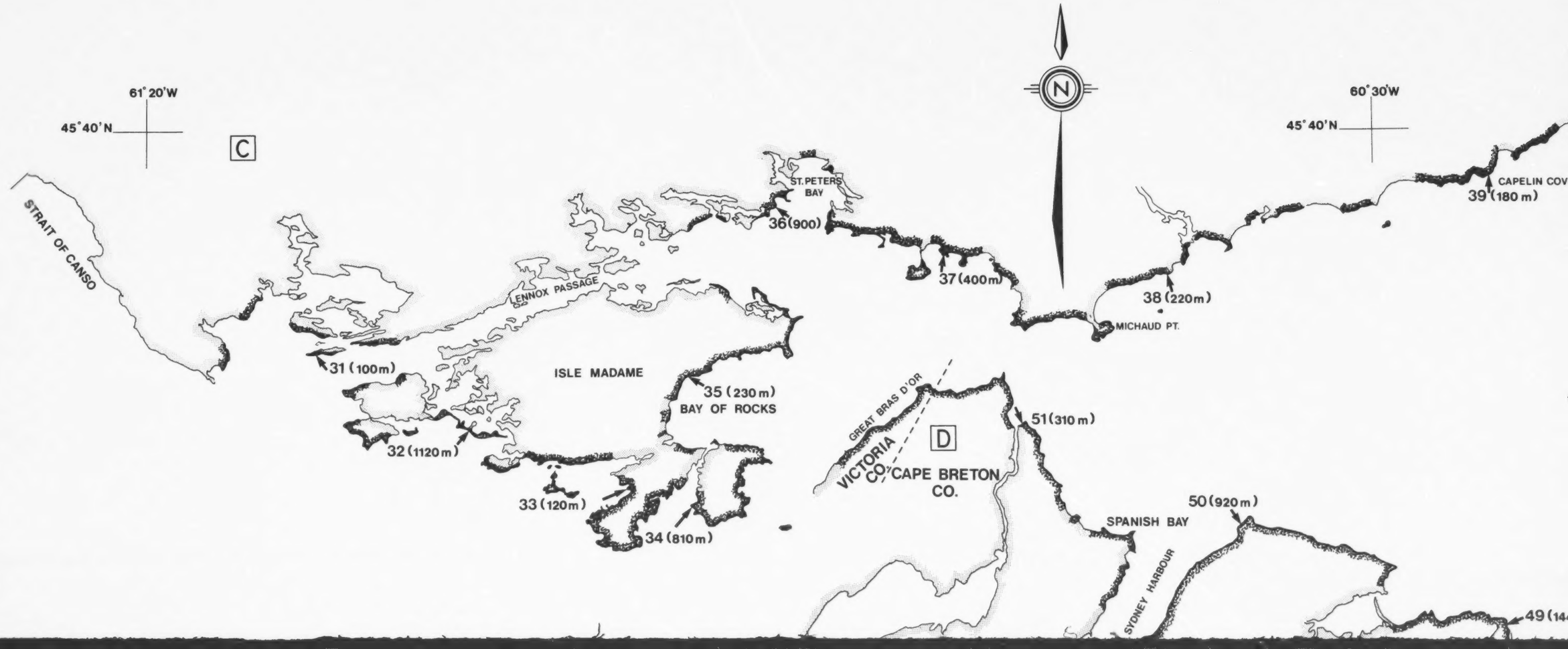
LEGEND

SHORELINE ADJACENT TO SEA BOTTOM SUITABLE FOR MACROPHYTES AND SEA URCHINS (HARD BOTTOM)

SHORELINE ADJACENT TO SEA BOTTOM UNSUITABLE FOR MACROPHYTES AND SEA URCHINS (SOFT BOTTOM)

TRANSECT NUMBER, LENGTH IN METERS

THERMOGRAPHS


61° 20'W
45° 40'N
C
STRAIT OF CANSO
LENNOX PASSAGE
ISLE MADAME
31 (100m)
32 (1120m)
33 (120m)
34 (810m)
35 (230m)
BAY OF ROCKS
ST. PETERS BAY
36 (900)
37 (400m)
38 (220m)
MICHAUD PT.
60° 30'W
45° 40'N
39 (180 m)
CAPELIN COV
GREAT BRAS D'OR
VICTORIA CO.
CAPE BRETON CO.
D
51 (310 m)
50 (920 m)
SPANISH BAY
SYDNEY HARBOUR
49 (14
N

ST. LAWRENCE BAY
59
(520m)

41(420m)

CAPE BRETON CO.

ASPY BAY

FOURCHU BAY

58(560m)

RICHMOND CO.

FOURCH HBR.

40 250m)

60°30'W

46° 50' N

57 (110m)

60°30'W

45° 40'N

CAPELIN COVE

39 (180 m)

ST. PETERS BAY

(900)

37(400m)

38(220m)

MICHAUD PT.

E

56 (820 m)

GREAT BRAS D'OR

VICTORIA CO.

D

CAPE BRETON CO.

51(310 m)

VICTORIA CO.

INGONISH HBR.

55
(180m)

50(920m)

SPANISH BAY

SYDNEY HARBOUR

49(1440m)

33 (120m)

34 (810m)

VICTORIA CO.

CAPE BRETON CO.

SPANISH BAY

50 (920m)

SYDNEY HARBOUR

49 (14

GLAC

60°20'W

46°10'N

LEGEND

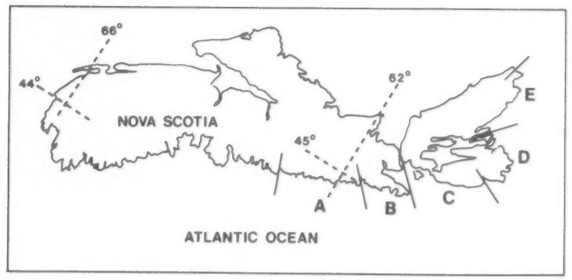
- SHORELINE ADJACENT TO SEA BOTTOM SUITABLE FOR MACROPHYTES AND SEA URCHINS (HARD BOTTOM)
- SHORELINE ADJACENT TO SEA BOTTOM UNSUITABLE FOR MACROPHYTES AND SEA URCHINS (SOFT BOTTOM)
- TRANSECT NUMBER, LENGTH IN METERS
- THERMOGRAPHS

CAPE BRETON CO.

0 10 km

47 (

MIRA BAY



LOUISBURG

43

(220m

42 (180m)

GABARUS BAY

41 (420m)

60°00'W

45°50'N

VICTORIA CO.

CAPE BRETON CO.

SPANISH BAY

SYDNEY HARBOUR

50 (920 m)

49 (1440m)

GLACE BAY

60°20'W

46°10'N

MORIEN BAY

48 (40m)

CAPE BRETON CO.

47 (280 m)

MIRA BAY

44 (190m)

LOUISBURG

43 (220m)

42 (180m)

GABARUS BAY

60°00'W

45°50'N

41 (420m)

0 10 km

VICTORIA CO.

INGONISH HBR.

55 (180m)

54 (680 m)

45 (110m)

SCATARIE ISLAND

46 (170m)

ST. ANNS BAY

60°30' W

46°20'N

MURRAY PT.

53 (80m)

52 (240)

ST. ANNS HBR.

GREAT BRAS D'OR

LEGEND

RELINE ADJACENT TO SEA BOTTOM ABLE FOR MACROPHYTES AND SEA HINS (HARD BOTTOM)

RELINE ADJACENT TO SEA BOTTOM UITABLE FOR MACROPHYTES AND URCHINS (SOFT BOTTOM)

NSECT NUMBER, LENGTH IN METERS

RMOGRAPHS